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SMITHSONIAN INSTITUTION,
UNITED STATES NATIONAL MUSEUM.

BULLETIN

OF THE

UNITED STATES NATIONAL MUSEUM.

No. 42.

A PRELIMINARY DESCRIPTIVE CATALOGUE OF THE SYSTEMATIC
COLLECTIONS IN ECONOMIC GEOLOGY AND METALLURGY
IN THE U. S. NATIONAL MUSEUM.

BY

FREDERIC P. DEWIES.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1891.

ADVERTISEMENT.

This work (Bulletin No. 42) is one of a series of papers intended to illustrate the collections belonging to the United States, and constituting the National Museum, of which the Smithsonian Institution was placed in charge by the act of Congress of August 10, 1846.

The publications of the National Museum consist of two series—the Bulletins, of which this is No 42, in continuous series, and the Proceedings, of which the fourteenth volume is now in press. A small edition of each paper in the Proceedings is distributed in pamphlet form to specialists in advance of the publication of the bound volume.

The Bulletins of the National Museum, the publication of which was commenced in 1875, consist of elaborate papers based upon the collections of the Museum, reports of expeditions, etc., while the Proceedings facilitate the prompt publication of freshly-acquired facts relating to biology, anthropology, and geology, descriptions of restricted groups of animals and plants, the discussion of particular questions relative to the synonymy of species, and the diaries of minor expeditions.

Other papers, of more general popular interest, are printed in the Appendix to the Annual Report.

Full lists of the publications of the Museum may be found in the current catalogues of the publications of the Smithsonian Institution.

Papers intended for publication in the Proceedings and Bulletins of the National Museum are referred to the Committee on Publications, composed as follows: T. H. Bean, A. Howard Clark (editor), R. E. Earll, Otis T. Mason, John Murdoch, Leonhard Stejneger, Frederick W. True, and Lester F. Ward.

S. P. LANGLEY,

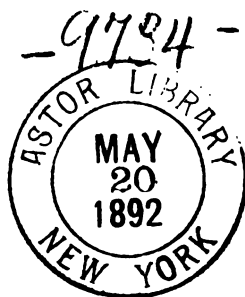
Secretary of the Smithsonian Institution.

WASHINGTON, D. C., October 5, 1891.

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EXPLANATION OF PLATES.

PLATE I (Page 2).

Plan of Installation of Collections.

Contents of cases:—Case 1, gold, minerals and ores. Case 2, gold, extraction and application; iridosmine. Case 3, silver, minerals and ores. Case 4, silver, ores and extraction. Case 5, silver, extraction; lead minerals; silver-lead, ores. Case 6, silver-lead, ores and smelting. Case 7, refining base bullion; lead, ores. Case 8, lead, ores. Case 9, pig and white lead, Lone Elm; white lead, Dutch. Case 10, copper, minerals and ores, Lake Superior region. Case 11, copper, ores, Lake Superior region. Case 12, copper, ores, Lake Superior region. Case 13, copper, smelting. Case 14, copper, smelting. Case 15, copper, smelting. Case 16, copper, smelting and application. Case 17, iron, minerals and ores, Tenth Census. Case 18, iron, ores, Tenth Census. Case 19, iron, ores, Tenth Census. Case 20, iron, ores, Tenth Census. Case 21, iron, ores, Tenth Census. Case 22, iron, ores, Tenth Census. Case 23, iron, ores, Tenth Census. Case 24, iron, ores, Tenth Census. Case 25, iron, ores, Tenth Census. Case 26, iron, ores, Tenth Census; manganese, ores. Case 27, iron, extraction, wrought iron, and cementation steel. Case 28, iron, extraction, Bessemer steel. Case 29, iron, extraction, pig iron. Case 30, iron, extraction, pig iron. Case 31, iron, application, Fagersta steel tests. Case 32, iron, application, Fagersta steel tests. Case 33, nickel and cobalt, minerals, ores, and application. Case 34, zinc, minerals and ores. Case 35, zinc, preparation of blende and extraction. Case 36, zinc, extraction. Case 37, tin, antimony, chromium, and bismuth, minerals and ores. Case 38, mercury, minerals and ores; aluminium, minerals and extraction. Case 39, alloys. Case 40, alloys and tin plate. Case 41, sulphur, minerals, ores and application; grinding and polishing materials. Case 42, grinding and polishing materials. Case 43, asbestos. Case 44, phosphates. Case 45, clays. Case 46, graphite. Case 47, anthracite coal. Case 48, anthracite coal. Case 49, semi-anthracite coal. Case 50, semi-bituminous coal. Case 51, bituminous coal. Case 52, bituminous coal, peat. Case 53, petroleum. Case 54, petroleum. Case 55, petroleum. Case 56, petroleum. Case 57, coal-mining tools. Case 58, coal-mining tools.

PLATE II (Page 10).

GOLD.

Hydraulic mining.—Working face of the North Bloomfield Hydraulic Mining Company, North Bloomfield, California.

Shows along the foreground the sheet iron pipe in which the water is conveyed from the ditch to the nozzles, at the end of this is a pile of stones placed upon it to keep it steady, and beyond is a nozzle discharging a stream of water against the working face of gravel. At the left, in the background, is another pipe and several nozzles.

In the foreground, near the center, are two bed-rock channels, one of which is in use and through which the water may be seen pouring.

The full background shows the working face of gravel.

The man standing at the nozzle gives a gauge for vertical distances.

(Cat. No. 56595, U. S. N. M. From photograph.)

PLATE III (Page 26).

SILVER.

Silver milling.—Elevation of a mill for the chloridizing-roasting and amalgamation of silver ores.

At the top, on the left, is the stock house, for the reception of the ore from the mines, immediately below is the floor for the rock-breakers and for drying the ore. On the next floor below and to the right are the stamps; on this floor a door leads to the Stetefeldt furnace, the top of which may be seen farther along to the right. On the next floor of the mill a door admits the roasted ore to the pans; just below and to the right are the settlers. On the next floor are the agitators, and the door from this floor leads to the retort house. (Cat. No. 51188, U. S. N. M. From Rothwell's "Cost of Milling Silver Ores in Utah and Nevada.")

PLATE IV (Page 28).

SILVER.

Silver milling.—Interior of a pan mill on the Comstock Lode, Storey County, Nevada.

Along the right runs the track for bringing in the ore, prepared, either by simple stamping or stamping and roasting for milling. Next below is a row of pans, in which the amalgamation is secured. Below again is a row of settlers, in which the amalgam and mercury are separated from the ore. On the lowest level are the agitators, in which a small amount of amalgam and mercury are removed. Just beyond the agitators is a car loaded with the amalgam.

(Cat. No. 51658, U. S. N. M. From photograph.)

PLATE V (Page 30).

SILVER.

Silver milling.—Exterior of the Ontario Mill, Park City, Summit County, Utah.

The ore is drawn by teams from the mine to the mill along the road in the middle ground at the right, which deliver it to the stock house, covered by the upper gable of the main building. The second gable of the main building covers the drying floor and the stamp floor. To the right of the upper gable of the main building, partly concealed by smoke, is the top of the Stetefeldt furnace; below and in front of this are the dust chambers, and farther back, up the side of the hill, is the draft stack from the dust chambers.

The lowest gable of the main building covers the pan floor, and to the left and farther back, is the retort house. In front of the mill is a large deposit of tailings (Cat. No. 51189, U. S. N. M. From photograph.)

PLATE VI (Page 46).

SILVER-LEAD.

Base-bullion smelting.—General view of the works of the Colorado Smelting Company, South Pueblo, Colorado, generally called "Colorado Smelter."

In the background, at the left, are the works of the Colorado Coal and Iron Company; next to these are the residence of the manager, general and assay offices of the Colorado Smelter. In the middle ground, to the left, is the sampling mill, where all the ores are received, crushed if necessary, and sampled for assay and analysis, so as to ascertain their character, the treatment necessary, and how to mix them in the shaft-furnace charge. From the sampling mill a tramway leads to various parts of the works.

Near the center of the middle ground are the roasting stalls and draft stack; to the right are the ore bins and reverberatory roasters, with draft stack. In the middle of the foreground is the blacksmith shop; to the right of this is the engine house, and to the right of this the shaft furnace house, containing four furnaces, and at the extreme right is the draft stack of the shaft furnaces. In front of the engine house and shaft furnaces is the slag dump.

(Cat. No. 51092, U. S. N. M. From photograph.)

PLATE VII (Page 48).

SILVER-LEAD.

Base-bullion smelting.—Yard and roasting stalls of the Colorado Smelter.

At the left are a pile of coke and a pile of cord wood. Diagonally across the picture is the double line of roasting stalls, from several of which the tops are removed, so that the roasted ore can be taken out; in the centre of the row is the draft stack, and between the rows runs the tramway. In the background, at the left, the corner of the reverberatory roaster house shows; next this is the stack of the shaft furnaces; to the right of this are the ore bins, and behind them the shaft furnace house; at the extreme right is the engine house. (Cat. No. 51094, U. S. N. M. From photograph.)

PLATE VIII (Page 50).

SILVER-LEAD.

Base-bullion smelting.—Interior of the shaft furnace house at the tap-hole level, Colorado Smelter.

Shows piles of base bullion as cast, slag buggies, and various other tools, the outside of the crucible of the furnace, the slag tap with its water-cooled plate, the iron columns at the corners of the furnace supporting the walls above the crucible, and the bustle pipe, which supplies air to the tuyeres, surrounding the furnace.

(Cat. No. 51096, U. S. N. M. From photograph.)

PLATE IX (Page 68).

LEAD.

Pig lead and white lead smelting combined.—General view of the works of the Lone Elm Company, Joplin, Jasper County, Missouri, producing pig lead and white paint by smelting galena and collecting the fumes.

XIV BULLETIN 42, UNITED STATES NATIONAL MUSEUM.

At the right are the two bag houses for the collection of fumes; in front of these are the engine and boiler houses and draft stack; at the end of the engine house are the cooling tubes, through which the hot white paint passes to be cooled so that it may be collected in woolen bags; near these is the water tank, and beyond is the building containing the slag eye furnaces for purifying the fumes from the Scotch hearth furnaces, which are in the building in the background at the left; at the extreme left is a small building for the storage of fuel and quicklime.

(Cat. No. 50727, U. S. N. M. From photograph.)

PLATE X (Page 94).

COPPER.

Copper ore.—Plan on plane of belt of the workings of the Delaware Mine, Lake Superior Copper District, Michigan, up to September, 1894.

The full diagonal lines represent the cross veins with solid fillings. The cupriferous areas or chutes are roughly outlined by the broken lines. The shaded portions represent worked-out areas.

(Cat. No. 51201, U. S. N. M. From tracing by E. B. Kirby, E. M.)

PLATE XI (Page 140).

IRON.

Iron ore.—Rogersfield Mine.

Shows the incline going down into the mine, the pillars of ore left to support the roof, and the empty spaces left after the ore has been extracted.

(Cat. No. 54635, U. S. N. M. From photograph.)

PLATE XII (Page 142).

IRON.

Wrought iron smelting.—Interior of Belmont Forge, Chateaugay Lake, New York.

The first forge at the left is in full operation; below the working plate can be seen the cinder plate, with holes for drawing off the cinder; to the right, on a shelf, is a piggin for dashing water on the fire when it gets too hot; at the left of the forge is the air pipe going into the chimney, and on the right is the curved pipe delivering the heated air to the tuyeres. Below the curved pipe of the second forge is a water box for cooling heated tools. At the corner of the second forge is a shovel for handling the ore; there is a bloom in this forge being reheated; beyond is a pile of fine ore, which supplies this and the next forge. At the right is a pile of baskets of charcoal.

(Cat. No. 54623, U. S. N. M. From photograph.)

PLATE XIII (Page 142).

IRON.

Wrought-iron smelting.—Trip hammer run by a large water wheel in the Belmont Forge, Chateaugay Lake, New York.

Used to hammer (shingle) the loup to blooms and the reheated blooms to billets.

(Cat. No. 54617, U. S. N. M. From photograph.)

PLATE XIV (Page 142).

IRON.

Wrought iron smelting.—Shows a group of the tools used in operating the furnace at the Belmont Forge, Chateaugay Lake, New York. In the background on the left, are some finished blooms. In the center, behind the tools, is a pile of baskets filled with charcoal.

(Cat. No. 54625, U. S. N. M. From photograph.)

PLATE XV (Page 144).

IRON.

Steel smelting.—Bessemer converter. A is the body of the converter; Q the blast pipe; F the tuyere box; D the pinion, and R the rack by which the converter is rotated; S is the hydraulic cylinder working the rack R.

(Cat. No. 51202, U. S. N. M. From Kohn's Iron and Steel Manufacture.)

PLATE XVI (Page 146).

IRON.

Steel smelting.—Interior of Bessemer steel house, showing converter A, casting crane H, ladle G, with stopper M and mold K. L is a hood, to direct sparks and flames from the converter up the chimney.

(Cat. No. 51203, U. S. N. M. From Kohn's Iron and Steel Manufacture.)

PLATE XVII (Page 152).

IRON.

Pig-iron smelting.—Section and plan of a typical blast furnace.

A, air cylinder, operating bell C, for the introduction of the charge by levers B; D, waste-gas pipe; E, downcomer, carrying gas away to be used under the boilers and in the hot-blast stoves; F, explosion door; G, cleaning door of downcomer; H, gas main; I, extra high tuyere (not used); K, blast pipe, supplying air to the tuyeres; L, water-pipe, supplying water to cool heated portions of the crucible; M, M, tuyeres, through which air is blown into the furnace; N, N, cinder notches, for drawing off the cinder. The notch for drawing off the metal is not shown but is similar to the cinder notch, but lower down the furnace, in front; O, O, columns supporting mantel. This furnace is 74 feet by 19 feet, has an iron mantel supported on columns, and is lined with fire brick.

(Cat. No. 51004, U. S. N. M. From Fackenthal's Durham Blast Furnace.)

PLATE XVIII (Page 152).

IRON.

Pig-iron smelting.—Stock floor of a charcoal blast furnace.

Shows on the right fine-ore bin, next coarse-ore bin. In front of the coarse-ore bin is a buggy, in which ore is weighed, hoisted to the top of the furnace, rolled over the throat, and emptied by lowering the bottom of the buggy. Beyond the ore bin is the charcoal bin and a buggy for charging the charcoal, which is emptied by tipping it over the throat of the furnace onto the bell. At the left is a scale for weighing the charge. Over the ore bin is a rock breaker.

(Cat. No. 54630, U. S. N. M. From photograph.)

PLATE XIX (Page 154).

IRON.

Pig-iron smelting.—Casting-house floor of charcoal blast furnace, showing beds of molten cast-iron that has just been tapped from the furnace, and cast into pigs. The tap hole of furnace is obscured by the glare of the hot iron.

(Cat. No. 54633, U. S. N. M. From photograph.)

PLATE XX (Page 154).

IRON.

Pig-iron smelting.—Top of coke blast furnace, showing throat of furnace with charge of coke resting on the bell.

(Cat. No. 54637, U. S. N. M. From photograph.)

PLATE XXI (Page 156).

IRON.

Pig-iron smelting.—Fire-brick stoves for heating the blast of air before it goes into the furnace.

(Cat. No. 54641, U. S. N. M. From photograph.)

PLATE XXII (Page 156).

IRON.

Pig-iron smelting.—General view of Longdale furnace, Longdale, Alleghany County, Virginia.

At the right is a pile of crushed limestone, and above is an elevated tramway for bringing in supplies of ore, fuel, and fluxes. Beyond the tramway is a car being elevated to the top of the furnace, containing four buggies of material to be charged into the furnace. The furnace is built of brick, encircled by bands of iron. Behind the furnace is the casting house.

(Cat. No. 50719, U. S. N. M. From Photograph.)

PLATE XXIII (Page 184).

ZINC.

Spelter smelting.—Belgian furnaces of the Passaic Zinc Company, Jersey City, New Jersey.

Shows the furnace in full blast, the lower rows of condensers have the prolongs attached, while the upper two rows have not. White oxide of zinc is being formed from imperfect condensation at several of the condensers.

(Cat. No. 54626, U. S. N. M. From photograph.)

PLATE XXIV (Page 186).

ZINC.

Oxide smelting.—Oxide furnaces of the Passaic Zinc Company, Jersey City, New Jersey, in full blast.

The middle row of doors is for the introduction of the charge; the upper row is for admitting air to oxidize the volatilized zinc, and to cool the products of combustion; the lower doors are for withdrawing ashes and refuse that fall through the grate. The small pipes at the side of each furnace supply air to the furnaces under pressure (blast). The large pipes leading from the tops of the furnaces are to convey the oxide of zinc suspended in the products of combustion and air to the bags, where it is filtered out. In the front of each furnace is a pile of mixed ore and coal ready to be charged into the furnace.

(Cat. No. 51102, U. S. N. M. From photograph.)

PLATE XXV (Page 190).

MERCURY.

Mercury mining.—Labor or working space on 1,500-foot level, Randol shaft, of the New Almaden quicksilver mines, New Almaden, Santa Clara County, California.

At the top, on the left, is a carpenter fitting timber; below him is a pile of broken ore. In the center background are two men drilling a hole for a blast. Facing them is the solid ore. At the right timbers to support the roof may be seen.

(Cat. No. 51659, U. S. N. M. From a photograph taken by magnesium light.)

PLATE XXVI (Page 190).

MERCURY.

Mercury mining.—Buena Vista shaft and Randol planilla, New Almaden mines, Santa Clara County, California.

At the left is the shaft house, and diagonally across the picture is the planilla where the ores are assorted and dressed for smelting.

(Cat. No. 51661, U. S. N. M. From photograph.)

PLATE XXVII (Page 192).

MERCURY.

Mercury smelting.—General view of the reduction works of the New Almaden quicksilver mines, New Almaden, Santa Clara County, California.

At the left, in the background, are furnaces Nos. 1 and 2; in front of these is the track for bringing in the ore, and in front of these are the ore houses. In the middle background are several furnaces with their elaborate condensing apparatus. The single-slope roof, on the right, covers the ore bins. On the extreme right is a large flue running up the side of the hill to the chimney. In the middle foreground is the works office, connected with it are storehouses and sheds.

(Cat. No. 51660, U. S. N. M. From photograph.)

PLATE XXVIII (Page 192).

MERCURY.

Mercury smelting.—Reducing furnace No. 1, at New Almaden mines, New Almaden, Santa Clara County, California.

At the right of the building is the elevator which takes the ores to a floor above the furnace, where they are distributed by cars running on tracks. The square brick furnace is near the center of the building. The heating arrangements are obscured by the load of wood.

(Cat. No. 51662, U. S. N. M. From photograph.)

PLATE XXIX (Page 226).

COAL.

Coal breaker.—The breaker at the Ellangowan colliery, Shenandoah, Schuylkill County, Pennsylvania. The loaded cars enter on the left, and the coal, after breaking, descends the chute and is run into the cars below.

(Cat. No. 59143, U. S. N. M. From photograph.)

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PLATE XXX (Page 224).

COAL.

Slate picking.—Boys and disabled men at the Ellangowan colliery, Shenandoah, Schuylkill County, Pennsylvania, engaged in picking pieces of slate and bony coal from the broken material as it descends the chutes from the breaker to the pockets.

(Cat. No. 59018, U. S. N. M. From photograph.)

PLATE XXXI (Page 222).

COAL.

Coal breaking.—Breaker at Kohinoor colliery, Shenandoah, Schuylkill County, Pennsylvania. The coal and dirt planes are shown.

(Cat. No. 59016, U. S. N. M. From photograph.)

PLATE XXXII (Page 228).

COAL.

A mule trip.—A train of mine wagons, hauled by a mule, on its way from the mouth of the drift to the chutes.

(Cat. No. 59106, U. S. N. M. From photograph.)

PLATE XXXIII (Page 230).

COAL.

Group of miners.—A group of miners in their working costumes, just leaving the mouth of the drift on their way home.

(Cat. No. 59105, U. S. N. M. From photograph.)

PLATE XXXIV (Page 232).

COAL.

Coal plane.—A loaded car descending, and an empty one ascending the side of the mountain. The coal is being transported to market. The empty car is drawn away at the foot of the plane by a mule.

(Cat. No. 59104, U. S. N. M. From photograph.)

DESCRIPTIVE CATALOGUE OF COLLECTIONS IN ECONOMIC GEOLOGY AND METALLURGY IN THE U. S. NATIONAL MUSEUM.

By **FREDERIC P. DEWEY.**

INTRODUCTION.

The systematic collections in economic geology and metallurgy are designed to show the actual occurrence of each metal and the processes used in their extraction; to these are added illustrations of the occurrences of non-metallic ores and their utilization. The systematic collections should be carefully distinguished from the geographical collection.

The collections start in the case of each metal by showing the series of minerals in which the metal forms an important constituent. The specimens are selected to show each mineral in its best perfection in order that it may be seen just how the metals occur in the ores.

The next step is a series of ores selected to show the actually occurring material that is mined, together with the associates of the ore. In the case of the base metals there may not be much difference between the ore specimens and the mineral specimens, except the greater purity and perfection of the latter, and that an ore may contain several minerals of the same or even different metals, especially alternation products, which do not have a definite composition.

In the case of the precious metals, however, there may be a wide difference between the two, depending upon the manner of occurrence of the valuable portion of the ore. In the case of silver, one part distributed through a thousand parts of foreign material may constitute a paying ore; if, now, this one part be distributed through the remainder more or less evenly, it will not be possible to detect any silver mineral in the ore. If, however, the silver should be concentrated into separate portions through the mass, it might be possible to pick out distinctively silver minerals.

The same observations apply to gold, but in a much greater degree since gold is so much more valuable, and in some cases can be extracted at much less expense than silver. This is especially the case with the hy-

draulic gravels of California, where, in some instances, an average value of 5 or 6 cents worth of gold in a ton of the gravel has yielded a profit.

The gangue or material carrying the valuable mineral varies greatly and exercises much influence upon the processes to be followed in the extraction of the metal.

In many cases an ore contains more than one valuable metal, and frequently long and costly operations are required to separate the different metals, while in the other cases their separation is quite easy. In some cases a useful alloy can be smelted directly from ores containing more than one metal.

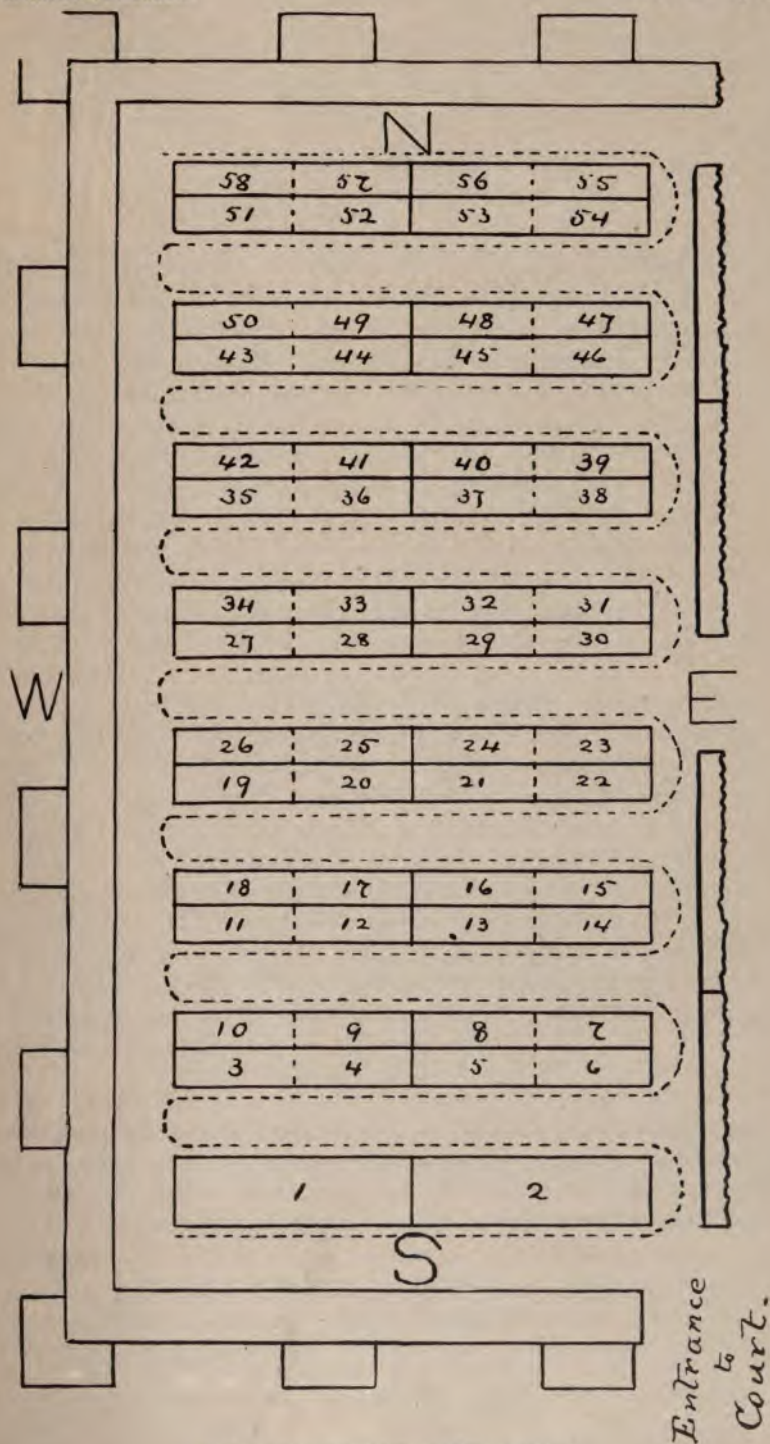
After the ore is mined it is frequently subjected to some kind of a concentrating process in preparation for smelting. These processes vary from simple sorting by hand, whereby much worthless material is removed, to very elaborate treatment by machinery, whereby the valuable portion of the ore is concentrated to a smaller volume and weight, generally with a loss of some of the valuable constituents, and the waste material is rejected. In some cases ore of different metals occurring together are separated from each other. Illustrations of these processes form the next step in the series, and consist of the ore as mined and the product of each step in the dressing operations, including both the valuable and the waste products.

The final step of the series represents the processes of extracting the metals from their ores and converting them into useful forms. These collections include the ores, the fuels, the fluxes, and all other materials entering into the operation, and the products, waste products, and by-products. To these in many cases are added various accessories, such as materials of construction and tools. Where there are different stages in the operation each stage is fully represented. To complete this step a few illustrations of the application of metals are shown. Several of these show metal working rather than metal producing.

The nonmetallic ores are treated in the same general way as the metallic ores.

The basis of these collections was exhibited at the New Orleans Exposition, but they have been much enlarged and improved since then. The collections described are but a beginning of the subject, and while generally complete in themselves will require many additions to even approach a full illustration of the subject.

The collections are installed in the west half of the southwest corner of the Museum. The accompanying diagram (PL. I) shows the arrangement and method of installation. Numbers 1 and 2 are low flat cases, the rest are upright cases, and the numbers refer to a single panel or pair of doors. To examine the collection systematically one should follow the dotted lines.



PLAN OF INSTALLATION OF COLLECTIONS.
(See explanation, page XL.)

G O L D.

GOLD MINERALS.

GOLD.

Composition: Au. Gold, containing silver in varying proportions, and sometimes also traces of copper, bismuth, palladium, and rhodium.

It crystallizes in the isometric system, especially in octahedrons and dodecahedrons. Complex and distorted crystals are common, the latter in reticulated and arborescent shapes. Its most common occurrence is in crystals and crystalline aggregates, massive (non-crystalline), in fine and coarse sand, scales or flattened grains, thin plates of considerable size, and in large masses, the largest ever found being the "Welcome" nugget, weighing 2,218 ounces, found at Ballarat, Victoria, Australia.

It varies in hardness from 2.5 to 3, and when pure its specific gravity is 19.30, but impurities may raise it to 19.6 or lower it to 15.6. When pure its color is bright golden yellow, but the presence of silver lightens the color very much. It has a full metallic luster and is very ductile and malleable.

Almost all the gold produced is found in the metallic state, and it has three prominent modes of occurrence: First, placer gold, in water-worn sands and masses from the beds of streams, either ancient or modern, and on the sea shore; second, quartz gold, crystals, and both crystalline arborescent and non-crystalline masses, imbedded in quartz or in cavities in quartz; third, sulphuret gold, generally invisibly disseminated through various sulphurets, especially pyrite and chalcopyrite, and occasionally mispickel. The two latter modes of occurrence are generally associated and graduate into each other, no large masses of quartz being without sulphides and no large masses of sulphides being without quartz. A small amount of gold is also found imbedded in other materials, especially slate.

PLACER GOLD.

Ten specimens have been selected to illustrate the most common occurrence of placer gold, beginning with a well-crystallized specimen that has been but little water-worn, and following through various stages, up to a single large nugget, weighing an ounce, which has been much water-worn. No. 11 is a sack used to carry gold dust.

(1) Crystallized, showing especially the branching forms of crystallization. June, 1872. Greenwood district, Cedarberg, El Dorado County, California. (55779.)

(2) Containing quartz, from a 24-ounce mass, showing crystals. September, 1879. Miller's claim, Deadwood Gulch, Deer Lodge County, Montana. (55472.)

(3) Dust, obtained by hand and long-tom washing. October, 1850. Meyer's claim, Feather River, California. (55479.)

(4) Dust, from pan-washing. September, 1879. Bingham Cañon, Utah. (55468.)

(5) Coarse flake, from hydraulic washings. October, 1868. Washington claim, Butte County, California. (55473.)

(6) Dust. First discovery in California, from tail race 200 yards below the mill, panned by J. W. Marshall on the evening of the 19th and 20th of January, 1848. Marshall's claim, Sutter's mill, Coloma, El Dorado County, California. (55480.)

(7) Spire gold, high grade, from hydraulic washings in ancient river bed. November, 1855. Blue Gravel lead, Swartzville, California. (55477.)

(8) Nugget, obtained by pan-washing. October, 1863. Foothills, Jacksonville, near branch of Rogue River, Oregon. (55466.)

(9) Nuggets. November, 1865. Williams' claim, Boise Basin, Placerville, Idaho. (55464.)

(10) Nugget from the first discovery claim. Weight, 1 ounce. October, 1869. Loon Creek, Boise County, Idaho. (55467.)

(11) Gold-dust sack. Made of buckskin and used for holding gold dust. (30533.)

QUARTZ GOLD.

To illustrate quartz gold fifteen specimens are shown, beginning with crystallized gold in a cavity in quartz, and following through various stages of crystallization of the gold and decomposition of the matrix to a natural alloy of gold and silver in wholly decomposed material.

(1) Free gold, crystallized in a cavity in quartz, with a little pyrite. Plumas Eureka Mine, Plumas County, California. (15048.)

(2) Free gold, crystallized on ferruginous quartz. Brewer Gold Mine, Chesterfield County, South Carolina. (55546.)

(3) Free gold, crystallized in ferruginous quartz. Love's mine, Richardsville, Culpeper County, Virginia. (30927.)

(4) Free gold, crystallized in quartz. Ellis Mine, Union County, Georgia. (5195.)

(5) Free gold, in quartz stained by decomposition products. Whytlatch Union Mine, Owyhee Park district, Lewis and Clarke County, Montana. (11140.)

(6) Free gold, in quartz. Narcococchee Mine, White County, Georgia. (5199.)

(7) Free gold, in quartz stained with iron. Valparaiso Mine, Amador County, California. (14975.)

(8) Free gold, in quartz. Norman Mine, Amador County, California. (14982.)

(9) Free gold, in quartz, the white and pure quartz carrying the gold appearing like a vein in an impure ferruginous quartz. Republic Mine, Bivens Gulch district, Madison County, Montana. (11082.)

(10) Free gold, finely disseminated through quartz. Gambrinus Mine, Boise County, Idaho. (14770.)

(11) Free gold, in ferruginous quartz. The gold in thin flakes is quite evenly distributed through the quartz. Kennet Extension Mine, Madison Range District, Madison Co., Montana. (11080.)

(12) Free gold, in quartz containing sulphurets that have been very much decomposed. Whytlatch Union Mine, Owyhee Park district, Lewis and Clarke County, Montana. (10921.)

(13) Free gold, in the ferruginous pebbles of a conglomerate. Lone Star Mine, Nevada Springs, Nevada County, California. (14935.)

(14) Free gold, in quartz and also in galena. No. 6 Mine, Cherokee County, North Carolina. (5239.)

(15) Gold, alloyed with considerable silver in decomposed material; from 400 feet deep. Silver Hill Mine, Comstock Lode, Storey County, Nevada. (15229.)

SULPHURET GOLD.

Two specimens of crystallized pyrite are shown to illustrate the occurrence of sulphuret gold. Since the gold is entirely invisible there

is nothing to indicate the presence of gold in these specimens. Further illustrations of this occurrence will be found in the ore series. Auriferous sulphurets consist of a more or less intimate mixture of the sulphide of iron (pyrite) and the double sulphide of iron and copper (chalcopyrite). Both of these sulphides are frequently supposed to be free gold, and pyrite is commonly known as "fool's gold."

(1) Auriferous pyrite, crystallized in quartz. Keating lode, Cedar Plains mining district, Keatingville, Jefferson County, Montana. (5483.)

(2) Auriferous pyrite, crystallized in quartz. Bates Mine, Nevada District, Gilpin County, Colorado. (19230.)

AURIFEROUS SLATE.

A single illustration of the occurrence of free gold in slate is shown.

(1) Free gold and pyrite in slate, with a little quartz. Gustin Mine, Lawrence County, Dakota. (20153.)

SYLVANITE. (GRAPHIC TELLURIUM.)

Composition (Au. Ag.), Te_2 . Telluride of gold and silver, containing gold 25 to 30 per cent., silver 7.5 to 15 per cent., and tellurium 45 to 60 per cent.; frequently antimony replaces the tellurium and lead the silver.

It crystallizes in the monoclinic system in complicated crystals; also occurs massive. It varies in hardness from 1.5 to 2, and in specific gravity from 7.9 to 8.3, has a steel-gray color and a metallic luster.

A somewhat rare mineral, although it has been found in large amounts in a few Colorado mines. A single illustration of telluride of gold is shown here; others will be found in the ore series.

(1) With pyrite, in quartz. American Mine, Sunshine district, Boulder County, Colorado. (19092.)

GOLD ORES.

For the purpose of extracting the metal the ores of gold may be divided into placer, including hydraulic, quartzose, sulphuret, telluride, and fusion ores.

PLACER GOLD.

Placer gold ore consists of the ordinary sands and gravels of rivers carrying free gold, and sometimes auriferous sulphurets, which have been deposited in the channel of the streams. Many of these beds are very old, and it is long since water flowed over them. Some are overlaid by recent lava flows. Where these ores occur in vast deposits they are called hydraulic ores, from the methods used in extracting the gold. Placer ores also occur on the seashore. The gold is scattered very irregularly through the sand, being found in largest amounts where eddies in the streams favored its deposition.

The gold is separated from the sand by washing, which consists in keeping the material agitated in water, in a suitable apparatus, so that

the lighter material will float away leaving the gold and heavier minerals behind. Mercury is often used to catch and hold the gold. Nuggets of gold of considerable size are picked by hand from the ore, and occasionally very large masses are found.

The simplest of all washing tools is the pan or batea, in which the ore is broken up in successive portions of water, the large pebbles picked out by hand and the lighter material removed by giving the water a peculiar circular motion. This operation is continued until nothing but the gold and heavier minerals remain. A final delicate manipulation spreads the material in the pan into a form like a fan with the gold at the point, and it can then be scraped out of the pan free, or nearly so, from the heavy minerals. This process is applicable only to the richer portions of the deposits.

Poorer ores are treated in various hand-rocking arrangements, such as cradles and long toms, through which water runs while the ore is thrown in and broken up, both by the water and the shovel. Still poorer ores are treated in ditches and channels, where the heavy materials are caught by riffles, and sometimes reworked in rockers.

For carrying on the extraction of placer gold a good supply of water is required, and the absence of sufficient water limits the working of some deposits to the richest portions, while the working of other deposits is prohibited altogether by this cause. The extraction of gold from this material is very irregular and uncertain, especially in newly discovered regions, since there is no way of predicting the richness or extent of the sand.

Gold separated from placer deposits is fully illustrated in the free gold series of mineral specimens.

To illustrate the special variety of placer gold, known as hydraulic gravel, five specimens are shown:

(1) Showing several flakes of free gold, rich material; taken 18 feet above bed rock, 46 feet above bottom of chamber. (The specimen has been varnished to prevent disintegration.) French Corral Mine, Nevada County, California. (14864.)

(2) Showing the ordinary run of the material. (The specimen has been varnished to prevent disintegration.) French Corral Mine, Nevada County, California. (14865.)

(3) Showing free gold. Indian Hill Gravel Mining Company, Gold Run, Placer County, California. (14878.)

(4) Showing the ordinary run of the material. (The specimen has been varnished to prevent disintegration.) Cherokee Butte Mine, Cherokee Flat, Butte County, California. (14883.)

(5) Showing the ordinary run of the material. Brewer Mine, Chesterfield County, South Carolina. (55539.)

QUARTZOSE GOLD ORES.

These ores are generally known as gold quartz or gold-bearing or auriferous quartz, but frequently contain large amounts of other material besides quartz.

They consist of quartz of several kinds, generally amorphous, but frequently crystallized, and generally milk white to colorless, but very often colored by iron; this coloring may be due to the stains from the recent decomposition of iron minerals, especially pyrite, or it may be an original ingredient of the quartz. Through this quartz gold is scattered, varying from invisibly fine particles to coarse gold plainly visible. Sometimes considerable masses are found.

The quartz frequently contains other minerals, especially silicates and sulphides; these latter sometimes occur in large amounts, and are generally auriferous, in fact quartzose ores graduate insensibly into the sulphuret ores.

The ores occur in several kinds of veins and also as rock strata, but the richness of the various parts of a deposit may be very different, and under some conditions certain parts may not be rich enough to be profitably mined with the appliances at hand.

The universal process for extracting the gold from quartzose ores is to crush the ore and submit it to the action of mercury, which forms a heavy amalgam with the gold, and separates it from the gangue material. After the gold has been extracted, the auriferous sulphides are generally separated and treated for the gold they contain. Although this process is not represented in the collections, it is essentially the same as the sulphuret process, illustrated by a collection from the Blackhawk Mill, Blackhawk, Gilpin County, Colorado.

Besides the specimens of gold quartz in the mineral series, which are simply rich quartzose ores with visible gold, the following characteristic specimens of quartzose ores are shown. The series begins with pure white quartz containing a very small amount of pyrite, and continues with increasing amounts of pyrite and slate to the last two specimens which are only about one-half quartz.

(1) Containing a few crystals of pyrite. Washington Mine, Mariposa County, California. (14506.)

(2) Containing pyrite and slate. Chariot Mine, Banner district, Inyo County, California. (14850.)

(3) Crystallized, containing pyrite and galena. New York Hill Mine, Grass Valley, Nevada County, California. (14959.)

(4) Containing galena and slate. Salsig Mine, Auburn district, Placer County, California. (15056.)

(5) Containing a little pyrite and decomposed silicates. Pennsylvania Mine, Nevada City, Nevada County, California. (14928.)

(6) Stained by decomposition products. Sierra Butte Mine, Sierra Butte district, Butte County, California. (15021.)

(7) Containing several slaty veins. Chariot Mining Company, Banner district, Inyo County, California. (65355)

(8) Intimate mixture of quartz, pyrite, and slate. Keystone Mine, Sutter Creek district, Amador County, California. (14994.)

(9) Containing large amounts of various sulphurets, pyrite, chalcopyrite, galena, blende (sulphides of copper, iron, lead, and zinc). Plumas Eureka Mine, Plumas County, California. (15049.)

SULPHURET GOLD ORES.

These ores consist of the sulphide of iron, pyrite, the sulphide of iron and copper, chalcopyrite, and the sulph-arsenide of iron, mispickel, the two former are by far the most common and always occur together. Occasionally other sulphides are associated in small amounts with those named. The sulphides of iron and copper generally occur in a gangue of quartz, which is also auriferous, and these ores are sometimes simply portions of quartzose veins, containing large amounts of sulphides. Mispickel generally occurs with a gangue of calcite or dolomite. The general occurrence of these ores is the same as the quartzose ores.

The gold in sulphuret ores occurs in practically two distinct forms; the first form amalgamates readily with mercury and can thus be separated by that means; but after most prolonged and careful treatment with mercury there will always remain some gold in the sulphides. It is claimed that the gold that amalgamates occurs as free gold in the sulphides, while that which will not amalgamate occurs in a chemically combined condition, but this distinction has not been fully proved, and it seems more probable that all the gold occurs in the free state, but that the portions that will not amalgamate are protected by the physical condition of the sulphides.

For the extraction of the gold the ores are first crushed and subjected to amalgamation. The sulphides are then separated from the gangue, and further treated.

Sometimes the concentrates are simply roasted to remove the sulphur and again amalgamated; sometimes after roasting the gold is dissolved by chlorine gas in water, the solution containing the gold is filtered off and the gold recovered from the solution. Sometimes the roasted ore is used in some of the smelting processes, and this is especially the case when it contains copper. Aside from the gold value these roasted sulphides are very useful in fusion processes on account of the iron they contain, which acts as a basic flux.

Mispickel ores are generally roasted previous to amalgamation to remove the arsenic as well as the sulphur.

The following ten specimens illustrate sulphuret gold ores:

- (1) Pyrite in quartz. Curraha Mine, Gainesville, Hall County, Georgia. (30834.)
- (2) Pyrite, crystallized in quartz. Gold Tunnel Mine, Nevada City, Nevada County, California. (14940.)
- (3) Pyrite in quartz. Gold Dirt Mine, Gold Dirt district, Gilpin County, Colorado. (19209.)
- (4) Pyrite and chalcopyrite, with a little quartz. Gregory Mine, Gregory district, Gilpin County, Colorado. (19223.)
- (5) Chalcopyrite in quartz. Bowery Mine, Ward district, Boulder County, Colorado. (19060.)
- (6) Intimate mixture of pyrite, chalcopyrite, galena, and blende. (Sulphides of copper, iron, lead, and zinc.) Bates Mine, Gilpin County, Colorado. (66356.)

(7) Pyrite, undergoing decomposition, and staining quartz. Ellis Mine, Culpeper County, Virginia. (33755.)

(8) Crystallized pyrite, almost wholly altered to the hydrated oxide of iron, with a little quartz. Narcocochee Mine, White County, Georgia. (65151.)

(9) Mispickel, (sulpharsenide of iron), crystallized in dolomite and quartz. Lake Mountain Mine, Sitka mining district, Alaska. (5656.)

(10) Mispickel, (sulpharsenide of iron) with quartz. Haley & Milstick Mine, near Silver Bay, Baranoff Island, Alaska. (34413.)

TELLURIDE ORES.

These ores consist of various tellurides of gold and silver, together with free gold and free tellurium in a gangue of quartz, occurring for the most part in veins, and associated with other ores. They are of limited occurrence, except in the case of a few Colorado mines, which at one time produced large amounts. The process of extracting the gold varies according to circumstances, the most simple being to roast the ore, whereby the tellurium is driven off, and the gold set free, and then to crush and amalgamate. Much of this kind of ore is treated by fusion processes.

To illustrate the telluride ores five specimens are shown :

(1) Tellurides in porphyry. Superior Mine, Sugar Loaf district, Boulder County, Colorado. (19273.)

(2) Roasted telluride ore, showing metallic gold set free by the roasting. Superior Mine, Sugar Loaf district, Boulder County, Colorado. (19270.)

(3) Tellurides, with a little pyrite in quartz. Cold Spring Mine, Gold Hill district, Boulder County, Colorado. (19072.)

(4) Tellurides and free tellurium, crystallized, with a little pyrite in quartz. Keystone Mine, Gold Hill district, Boulder County, Colorado. (19137.)

(5) Tellurides and free gold, with pyrite in quartz. American Mine, Sunshine district, Boulder County, Colorado. (19090.)

FUSION GOLD ORES.

These ores are generally ores of other metals besides gold, and the gold is separated during the process of separating the other metals. They may be broadly separated into auriferous copper ores, auriferous silver and lead ores, and a third class containing very variable ores. To this latter class belong many of the telluride ores. No especial collection of fusion ores is shown, but they can be seen in the collections from the Argo Works, Colorado, and the Balbach Works, Newark, New Jersey, and also as the auriferous varieties of the ores of other metals. In the latter case no especial distinction can be seen between the auriferous and non-auriferous varieties of the ores of other metals.

PROCESSES OF EXTRACTING GOLD.

HYDRAULIC GRAVEL DEPOSITS.

Along the slopes of the Sierra Nevada Mountains of California occur immense bodies of gravel, made up of a large variety of material, and while quartzose sand and pebbles predominate, yet other materials are

frequently found, especially volcanic products. Nearly all of this gravel is known to contain gold, yet much of it can not be worked from various causes, the most important being the lack of water, and the fact that the material is overlaid by a more or less heavy cap of lava. Recently operations have been stopped by the courts on account of the damage done to farmers along the streams by the large amounts of tailings that were discharged into the river.

A single workable deposit will sometimes cover hundreds of acres in extent, and be from 100 to 300 or even 400 feet in depth. The gold is generally more or less concentrated in certain strata, but it is only occasionally that these strata can be removed without moving the whole mass. The rich stratum or "pay" is sometimes found near the top, and also at various other levels, but it is generally confined to the region of the bottom or bed rock of the deposit. The average amount of gold that it is necessary that a deposit should carry in order to constitute a workable deposit varies greatly with circumstances, but, under moderately fair conditions, as small an amount as 4 cents worth of gold to a cubic yard of gravel will yield a reasonable profit.

The means used for breaking down the gravel and separating the gold from the worthless material is water, hence the name "hydraulic process." For this purpose it is necessary to construct immense reservoirs for the storage of water. These reservoirs are constructed high up in the mountains, frequently 50 or more miles away from the gravel deposit, and are very expensive. Several reservoirs hold more than 1,000,000,000 cubic feet of water each.

The water is brought from these reservoirs by means of ditches, flumes, and iron pipes, according to the character of country traversed, as near as possible, to the gravel deposit; it is then dropped down in nearly a straight and vertical pipe to the level of the bed-rock, where, by means of suitable pipes and nozzles, it is directed against the face of the gravel deposit. The pressure at which the water leaves the nozzle is very great, being seldom less than 50 feet, and sometimes being four to five hundred feet. When such a stream of water is properly directed against the gravel it disintegrates the deposit very rapidly and effectually. After the material is broken down it is carried along by the stream of water over the bed-rock, and then through a channel cut in the bed-rock to a series of sluices. A general view of the operation of this process is shown in PL. II.

A suitable amount of mercury is placed in the sluices which amalgamates with the gold, on coming in contact with it, and this amalgam, being very heavy, settles to the bottom of the sluices, and is held there by the riffles provided for that purpose.

At certain suitable intervals the stream of water is much reduced, so that no fresh material is washed down, and a "clean-up" is made. The gold that occurs in nuggets of any size is generally retained in the crevices and depressions on the bed-rock, and the sizes of the particles decrease with the distance from the working face. In the clean-up men



WORKING FACE OF NORTH BLOOMFIELD HYDRAULIC MINING COMPANY.
(See explanation, page XII.)

are sent out to gather up all the loose gold and follow along to the sluices, and there gather up the amalgam. This amalgam is properly purified and then heated in a retort to drive off mercury, which is then

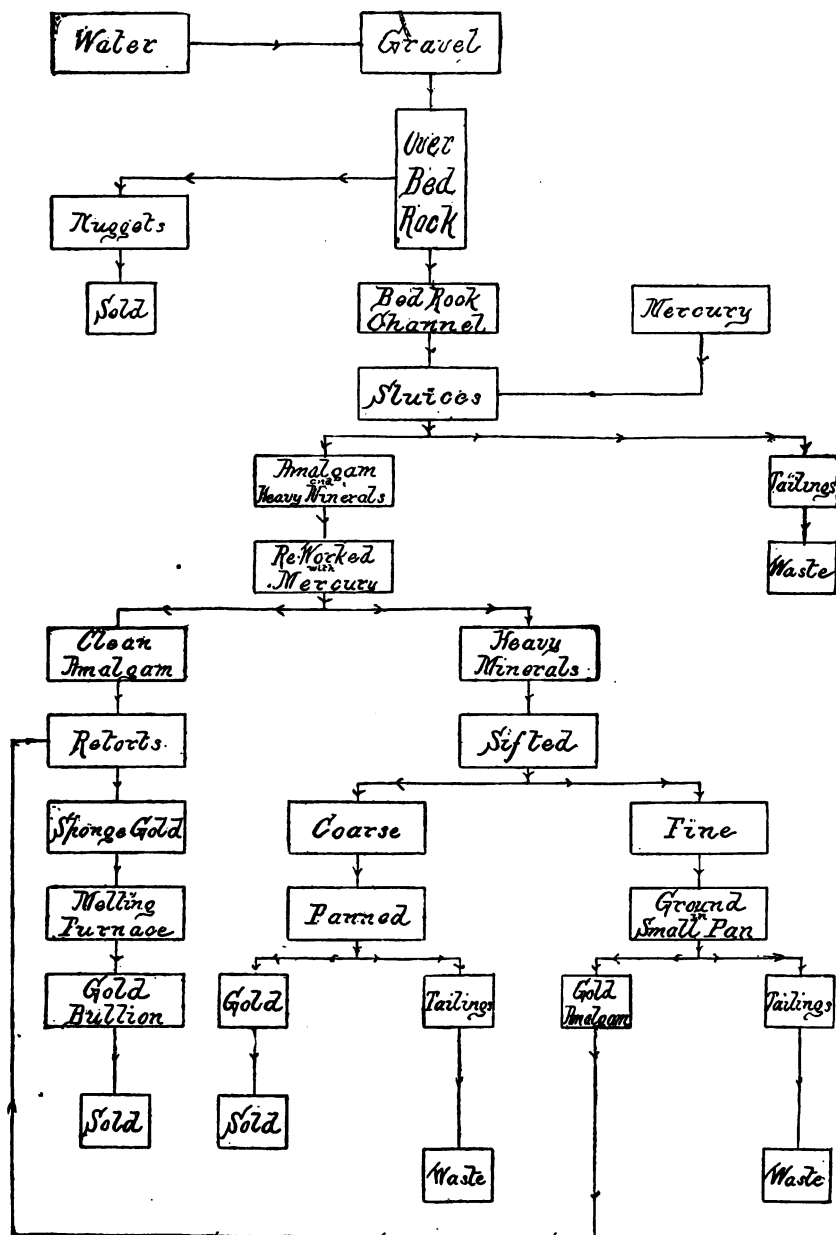


FIG. 1.
Scheme showing hydraulic mining.

ready for use again. The retorted or sponge gold is sold to the mint, as are also the nuggets and coarse dust.

In some cases the gold is so much concentrated into certain well-defined strata that they can be removed without disturbing the remainder of the deposit, by a system of mining known as drifting.

NORTH BLOOMFIELD MINE.

To illustrate the hydraulic process nine specimens are shown from the North Bloomfield Gravel Mine, North Bloomfield, Nevada County, California, one of the largest hydraulic mines in the State. The collection was made by Mr. W. H. Radford, superintendent, October, 1884.

- (1) Auriferous gravel, average fair quality, from 1 foot above bed-rock. (55404.)
- (2) Nuggets, obtained in cleaning up. (55316.)
- (3) Fine gold, from gravel lying directly on the bed-rock; obtained by the drifting process. (55315.)
- (4) Quicksilver or mercury, used to amalgamate and save the gold as it passes through the sluices. Squeezed from amalgam. (55312.)
- (5) Quicksilver or mercury, used to amalgamate and save the gold as it passes through the sluices. Distilled in retorting amalgam. (55313.)
- (6) Gold amalgam, taken from the sluices in cleaning up. Purified and squeezed amalgam. (55314.)
- (7) Sponge gold, obtained by heating the gold amalgam to drive off the mercury. (55317.)
- (8) Black sand, consisting of various heavy minerals, especially magnetite, pyrite, zircon, and cassiterite, obtained with the amalgam in the sluices when cleaning up. (55318.)
- (9) Sulphurets and heavy material, obtained in the clean-up in working over and purifying the amalgam. (55319.)

The operation of the process is further illustrated by the scheme as shown in Fig. 1.

THE EXTRACTION OF GOLD FROM SULPHURETED ORES BY STAMPING AND AMALGAMATING.

BOBTAIL MILL.

This process is illustrated by a collection from the Bobtail mill, Black Hawk, Gilpin County, Colorado.

The ore as delivered to the mill is first passed over screens to separate the fine and coarse material; the coarse material is crushed before being fed into the mortars, while the fine is fed direct. The mortars consist of cast iron receptacles, provided with a suitable bottom of cast-iron, that can be easily renewed. The sizes of the mortars vary according to circumstances, especially as regards depth. The front and back of the mortars are provided with amalgamated plates, to catch as much as possible of the gold during the crushing. Above the plates in the front of the mortar is an 80-mesh screen. A stream of water is kept flowing through the mixture during the crushing.

The ore being thrown into the mortar, the stamp is allowed to drop upon it in order to reduce it to the proper size. The stamp consists of a suitable piece of cast-iron on the end of a rod, that can be raised by

a cam motion, and allowed to fall by its own weight by suitable mechanical arrangements. The stamp weighs 500 pounds, and falls 16 inches, thirty times per minute. As the stamp falls upon the ore, it is crushed, and as soon as it is fine enough, it passes out of the mortar, through the screen, by the water flowing through the mortar. After passing the screen it is carried along over amalgamated silver-plated copper plates, which catch a still further portion of the gold. Below the plates there are arrangements for catching the amalgam that is carried along mechanically from the plates, and also to collect some of the richer portions of the material that will not amalgamate. After passing over these appliances the material passes through a concentrating process, whereby the waste material is separated and thrown away, while the sulphurets are separated, and further treated at other works.

These sulphurets as a general thing still retain about 10 per cent. of the gangue material, and from 0.5 to 1 ounce of gold per ton; they sometimes contain a valuable amount of copper, and when roasted form a useful flux for smelting operations on account of the iron they contain; they are in considerable demand for this purpose. Occasionally rich sulphurets are picked by hand from the ore and sold to the smelters.

To illustrate this process seven specimens collected by Mr. E. N. Rodgers, in November, 1884, are shown.

(1) Ore, consisting of various sulphurets, principally pyrite and chalcopyrite in quartz and feldspathic material; an average fair sample of the material treated at the mill. Bobtail Mine, Blackhawk, Gilpin County, Colorado. (55837.)

(2) Battery Pulp, showing the condition of the ore after it has been subjected to the pounding of the stamp in the battery and to the action of mercury, whereby a large portion of the gold is extracted. (55838.)

(3) Stock, or the ore after crushing, as it passes through the sieves and over amalgamated copper plates where the rest of the gold that will amalgamate is extracted. (55839.)

(4) Gold amalgam, as scraped from the copper plates, weighs 6 ounces and contains \$40 worth of gold. (55842.)

(5) Retorted amalgam, or gold sponge, weighs 2 ounces, 15 pennyweight, worth \$46. (55843.)

(6) Concentrates, consisting of the sulphurets that have been separated from the ore after the extraction of the gold, they yet contain about one ounce of gold per ton that can not be recovered by amalgamation; they are, therefore, sold to the smelting works where, after roasting, they serve as a valuable flux, as well as a source of gold, in the fusion process. (55840.)

(7) Sand or tailings, consisting of quartz and other waste material in the ore, thrown away as valueless. (55841.)

THE EXTRACTION OF SEVERAL METALS BY SMELTING.

To illustrate the extraction of gold by smelting, a series of fourteen specimens from the Newark Smelting and Refining Works of E. Balbach & Son are shown. The process followed at these works is a double one, embracing the separation of gold and silver from copper, and also combining the smelting operation with an electrolytic process.

These works are situated at a distance from any mining operation, and obtain their supplies wherever they can to the best advantage. The ores therefore are generally quite rich and vary constantly. As a consequence, the operations are somewhat complicated.

A suitable mixture of ore is made up, and with the proper fluxes submitted to a fusion, whereby the earthy material of the ore is separated into a slag, which is thrown away; while the metals are concentrated into a matte which contains most of the copper, with some of the iron of the ore, in the form of sulphides, and also the gold and silver.

This matte is further concentrated by roasting and fusing to a second matte, and this process of refining goes on until nearly pure metallic copper is obtained. Through all these operations the gold and silver remain with the copper.

The metallic copper is now subjected to an electric current in a suitable bath, generally of sulphate of copper, whereby the copper is dissolved at the anode, leaving the impurities containing the gold and silver behind, while pure copper is deposited on the cathode. This pure electrolytic copper is now ready to be worked up into merchantable forms. The residues, by a very simple operation, yield metallic gold and silver, which are readily separated.

Ores.

- (1) Gold-bearing quartz. (55668.)
- (2) Gold-bearing sulphurets, consisting of a mixture of pyrite and chalcopyrite with a little quartz. (55667.)

Fluxes.

- (1) Limestone. (55671.)
- (2) Fluor spar. (55672.)
- (3) Cinder, from an iron puddle furnace. (55673.)

Intermediate products.

- (1) First matte, obtained by smelting the ore, contains gold, silver, copper, and iron combined with sulphur. (55674.)
- (2) Slag, obtained in smelting first matte, is practically free from gold, silver, and copper and is rejected. (55675.)
- (3) Second matte, obtained by roasting and fusing first matte, whereby large amounts of sulphur and iron are removed. (55676.)
- (4) Black copper, obtained by roasting and fusing second matte, whereby nearly all the sulphur and iron are removed. (55677.)
- (5) Metallic copper, nearly pure, obtained by refining black copper. (55665.)
- (6) Sulphate of copper, obtained as a by-product and used in making up the bath for the electrolytic separation. (55670.)
- (7) Residues, remaining from dissolving the copper, No. 55665, in the electrolytic process, and containing the gold, silver, and other impurities of the copper. (55662.)

Final products.

- (1) Metallic copper, a sheet of pure copper deposited by the electrolytic process. (55661.)
- (2) Gold, fine metal, separated from the residues from the electrolytic process; weight, 1.3 ounces; value, \$27. (55681.)
- (3) Silver, fine metal, separated from the residues from the electrolytic process; weight, 10½ ounces; value, \$11.50. (55680.)

APPLICATION OF GOLD.

GOLD LEAF.

A single illustration of the application of gold is shown in the collection illustrating the manufacture of gold leaf from the works of Hastings & Co., Philadelphia, Pennsylvania. This collection begins with gold in sheets as thin as it is possible to roll it, and follows through the various stages of reducing its thickness, by beating between skins on a wooden block with a peculiar-shaped maul, until it is about $\frac{1}{7000}$ of an inch in thickness, which constitutes the ordinary gold leaf of commerce. The specimens are:

- (1) Ribbon of 23 $\frac{1}{2}$ karat gold, rolled as thin as possible between steel rollers. (51106.)
- (2) Ribbon, cut into convenient size for beating. (51107.)
- (3) Foil, produced by beating No. 51107 for half an hour with a 15-pound hammer. (51108.)
- (4) Foil, No. 51108, marked off into quarters. (51109.)
- (5) Foil, a quarter of No. 51109. (51110.)
- (6) Foil, obtained by beating No. 51110 for one hour with 12-pound hammers. (51111.)
- (7) Foil, No. 51111 marked off into quarters. (51112.)
- (8) Foil, a quarter of No. 51112. (51113.)
- (9) Foil, obtained by beating No. 51113 for five hours with 8-pound hammers. This specimen is inclosed in the skin used to inclose the foil during beating. (51114.)
- (10) Foil, commercial size of foil 3 $\frac{3}{8}$ inches square and $\frac{1}{7000}$ of an inch thick. (51115.)
- (11) One dollar coin, showing sufficient gold to make 100 sheets of No. 51115. (51116.)

IRIDOSMINE.

This is a natural alloy of the rare metals iridium and osmium, containing variable proportions of these metals, together with rhodium, platinum, and ruthenium. It carries from 43 to 77 per cent. iridium, and 17 to 48 per cent. osmium.

It crystallizes in the hexagonal system, but crystals are rare. It is generally found in flattened grains similar to gold dust, and associated with gold and platinum. It varies in hardness from 6 to 7, and in specific gravity from 19.3 to 21.12, has a full metallic luster and tin-white color, and is only slightly malleable.

Considerable amounts are found in washing for gold, especially in the beach sands of the Pacific coast.

Iridosmine is remarkable for its infusibility and resistance to all ordinary solvents; all single acids and even aqua regia fail to dissolve it. Iridosmine, as found, is used only for tipping the points of gold pens, but considerable amounts are required for this purpose. The naturally occurring material is carefully picked under a magnifying glass, and all the grains of proper size and shape are saved and utilized.

When iridosmine is sent to the mint with gold dust its removal causes considerable trouble. The plan now followed is to add a large amount

of silver to the metal and melt the mixture, and then allow the melt to stand some time. The grains of iridosmine do not alloy with the gold and silver, and being very heavy they settle to the bottom of the crucible. By carefully pouring off the top of the melt the iridosmine remains behind, with some silver and a little gold. The other metals are afterwards dissolved by acids, leaving the iridosmine.

By fusing iridosmine with phosphorus and treating the fused mass with lime at a high heat a nearly pure iridium is obtained, and this is finding application for purposes where resistance to corrosive influences is required. A small amount of oxide of iridium is used as a black color in decorating pottery.

To illustrate iridosmine seven specimens are shown. Four specimens from Randolph, Coos County, Oregon, represent the occurrence and associates of iridosmine.

(1) Sand, showing the material in which the gold and iridosmine are found. (64749.)

(2) Gold dust, containing a few flakes of iridosmine, together with some heavy material; obtained by washing the sand. (64747.)

(3) Iridosmine, in scales and dust, separated from the gold; contains a small amount, of platinum. (44296.)

(4) Black sand, consisting of various heavy minerals, especially magnetite, pyrite, zircon, cassiterite, and garnet, that collect with the metal in the washing operation. (64748.)

(5) Iridosmine, selected coarse scales, suitable for making pen points. California. (55407.)

(6) Iridosmine, selected fine scales, suitable for making pen points. California. (55406.)

(7) Iridosmine, separated from placer gold at the United States Mint, by fusing the gold with silver. (54971.)

SILVER.

SILVER MINERALS.

SILVER. (WIRE SILVER.)

Composition: Ag. Silver, generally containing a little gold and copper, and frequently other metals in very small amounts.

Silver crystallizes in the isometric system, especially in cubes and octahedrons, and in combinations of these. Crystals are frequently very much distorted, while compound and twin crystals are very common. Its most frequent occurrence is in the form of wires from $\frac{1}{8}$ inch in diameter down to hair-like and mossy masses, which are generally distorted octahedrons. It frequently occurs in arborescent or tree-like forms in which the branching takes place at sixty or ninety degrees, which are likewise distorted crystals. It also occurs in superficial coatings, crystallized and uncrystallized, and massive. Masses of several hundred weight have been found a number of times, and one mass at Sonora, Mexico, was said to weigh 2,700 pounds.

It varies in hardness from 2.5 to 3, and when pure its specific gravity is 10.5, but impurities may raise it to 11.1, or lower it to 10.1. It has a beautiful white color, which soon tarnishes on exposure. It has a full metallic luster, and is malleable and ductile.

It is an abundant source of silver, and is sometimes the chief product of a mine; this was especially so at the Silver Islet Mine, in Lake Superior. It is not limited to any level in its occurrences, being found at and near the surface as well as in very deep workings. In the former case it is frequently the result of the decomposition of other silver minerals, while in the latter it is an original silver mineral. To illustrate the occurrence of free silver, twelve specimens are shown.

(1) Coarse wire, with quartz and sulphides. Silver King Mine, Pinal County, Arizona. (65154.)

(2) Thick wire or spike, in calcite with galena and blende. Santa Domingo Mine, Batopilas, Mexico. (64961.)

(3) Wire or moss, in a cavity in quartz, together with various sulphides. Caribou Mine, Grand Island district, Boulder County, Colorado. (19292.)

(4) Wire, on galena. May Flower Mine, Wood River District, Idaho. (5666.)

(5) Arborescent plates, in quartz, with sulphides, especially galena. Monitor Mine, Philadelphia district, Nye County, Nevada. (15405.)

(6) Intimately mixed with various sulphides in quartz. Monitor Mine, Philadelphia district, Nye County, Nevada. (65366.)

(7) Very thin plates, on chalcocite. Gagnon Mine, Butte, Silver Bow County, Montana. (33766.)

(8) Very thin plates, on chalcocite. Gagnon Mine, Butte, Silver Bow County Montana. (65367.)

(9) Plates, filling crevices in decomposed material. American Flag Mine, Ely district, Pioche, Lincoln County, Nevada. (15302.)

(10) Plates, on indurated clay, part of the silver being altered to the chloride, cerargyrite. Two Ikes Mine, Silver City district, New Mexico. (10199.)

(11) Very thin plates, in decomposed material. Silver Reef district, Washington County, Utah. (55328.)

(12) Thin flakes, in fossiliferous sandstone, the silver being associated with the fossils. Stormont Mine, Silver Reef district, Washington County, Utah. (55331.)

ARGENTITE. (VITREOUS SILVER, SULPHURET OF SILVER, SILVER GLANCE.)

Composition: Ag_2S . Sulphide of silver, containing, when pure, silver 87.1 per cent. and sulphur 12.9 per cent.

It crystallizes in the isometric system, especially in cubes, octahedrons, and dodecahedrons. It also occurs in reticulated, arborescent, and filiform masses, and occasionally amorphous. It varies in hardness from 2 to 2.5, and in specific gravity from 7.19 to 7.36, has a lead-gray color, inclining to black, and a full metallic luster. It can be easily cut with a knife into thin shavings.

Argentite is an abundant source of silver, being found in many mines, especially below the water level. To illustrate the occurrence of argentite, five specimens are shown.

(1) A group of branching octahedrons. Batopilas, Mexico. (64973.)

(2) An imperfect crystal, in quartz, with other sulphides. Consolidated Virginia Mine, Comstock lode, Storey County, Nevada. (15171.)

(3) An imperfect crystal, in quartz, with other sulphides. Crown Point Mine, Comstock lode, Storey County, Nevada. (15446.)

(4) Crystalline aggregate, with quartz and other sulphides. Crown Point Mine, Comstock lode, Storey County, Nevada. (65368.)

(5) Crystallized, in quartz, with other sulphides. Ophir Mine, Comstock lode, Storey County, Nevada. (15192.)

STEPHANITE. (BRITTLE SILVER ORE.)

Composition: Ag_3SbS_4 or $5\text{Ag}_2\text{S} + \text{Sb}_2\text{S}_3$. Sulph-antimonide of silver, containing silver 68.5 per cent., antimony 15.3 per cent., and sulphur 16.2 per cent.

It crystallizes in the orthorhombic system, showing especially the basal, unit prism, and octahedron, brachy pinacoid, and brachy dome 2 planes. It also occurs more or less massive and disseminated through other material. It varies in hardness from 2 to 2.5, and its specific gravity is 6.269. It is iron-black in color and has a metallic luster. It is quite brittle, whence its name, brittle silver ore.

Stephanite is quite an important source of silver, being found in many mines, but the extraction of its silver is difficult, and the total yield from the mineral has not been large. To illustrate the occurrence of stephanite one specimen is shown.

(1) Crystallized, in quartz. Chollar Potosi Mine, Comstock lode, Storey County, Nevada. (15183.)

PYRRARGYRITE. (RUBY SILVER, DARK-RED SILVER ORE.)

Composition, Ag_3SbS_3 or $3\text{Ag}_2\text{S} + \text{Sb}_2\text{S}_3$. Sulph-antimonide of silver, containing silver 59.8 per cent., antimony 22.5 per cent., and sulphur 17.7 per cent.

It crystallizes in the rhombohedral system, crystals being somewhat complex and frequently twinned. It also occurs in granular masses and sometimes as impalpable powder. It varies in hardness from 2 to 2.5 and in specific gravity from 5.7 to 5.9; is black to dark red in color and opaque to translucent and has a bright metallic luster.

Pyrargyrite is a valuable source of silver and has yielded a considerable amount of the metal, but the extraction of the metal is somewhat difficult, and ores in which it is the chief mineral, as at Reese River, Nevada, must be very rich in order to pay the expense of working. When it is exposed to decomposing influences, as in the portions of a vein above water level, it is prone to change, argentite, cerargyrite, and silver being, at times, the result of its decomposition. To illustrate the occurrence of pyrargyrite, six specimens are shown:

(1) Crystallized, in quartz, with other sulphides. Little Emma Mine, Lump Gulch district, Jefferson County, Montana. (11151.)

(2) Well crystallized, in quartz, showing also a few small crystals of stephanite. North Star Mine, Reese River district, Lander County, Nevada. (15133.)

(3) Well crystallized, in quartz, showing also a few small crystals of stephanite. North Star Mine, Reese River district, Lander County, Nevada. (65369.)

(4) Crystallized and granular, in quartz, with other sulphides. Comargo Mine, Reese River district, Lander County, Nevada. (15156.)

(5) Crystallized and granular, in quartz, with other sulphides. Allison Mine, Carson district, Owyhee County, Idaho. (14806.)

(6) Intimately mixed with galena and blende, with a little quartz. Legai Tender Mine, Prickly Pear district, Jefferson County, Montana. (11156.)

PROUSTITE. (RUBY SILVER, ARSENICAL SILVER ORE, LIGHT-RED SILVER ORE.)

Composition: Ag_3AsS_3 or $3\text{Ag}_2\text{S} + \text{As}_2\text{S}_3$. Sulph-arsenide of silver, containing silver 65.5 per cent., arsenic 15.1 per cent., and sulphur 19.4 per cent.

It crystallizes in the rhombohedral system, and also occurs massive. It varies in hardness from 2 to 2.5 and in specific gravity from 5.42 to 5.56, is cochineal-red in color, transparent, and has an adamantine luster.

An interesting and important silver mineral, being found frequently with stephanite and pyrrargyrite, and like them being difficult to reduce.

HESSITE. (TELLURIC SILVER.)

Composition: Ag_2Te . Telluride of silver, containing silver 62.8 per cent. and tellurium 37.2 per cent.

It crystallizes in the orthorhombic system and occurs also massive. It varies in hardness from 2 to 3.5 and in specific gravity from 8.3 to 8.6, has a lead-gray color and metallic luster, and can be readily cut with a knife.

An important silver mineral in a number of Colorado mines.

TETRAHEDRITE. (FAHLERZ, GRAY COPPER ORE.)

Composition: $\text{Cu}_8\text{Sb}_2\text{S}_7$ or $4\text{Cu}_2\text{S} + \text{Sb}_2\text{S}_3$, with part of the copper replaced by iron, zinc, mercury, or silver and part of the antimony by arsenic or bismuth, thus forming a very complex composition. In the varieties containing silver it sometimes amounts to 31 per cent., but is more frequently less than 10 per cent.

It crystallizes in the isometric system, especially in tetrahedrons (whence its name), and crystals are frequently very complex. It also and very frequently occurs massive. It varies in hardness from 3 to 4.5 and in specific gravity from 4.5 to 5.11, and in color from gray to black, and has a full metallic luster.

Tetrahedrite, while essentially a copper mineral, is generally more valuable for its silver contents, although very variable in richness, and the extraction of the silver is intimately connected with the metallurgy of copper.

To illustrate the occurrence of tetrahedrite four specimens are shown:

(1) Massive, with a little quartz. Witteknit Mine, Inyo County, California. (8272.)

(2) Massive, in quartz, very much stained by carbonates of copper from the decomposition of the tetrahedrite. Stewart's Wonder Mine, Panamint district, Inyo County, California. (14831.)

(3) Massive, in quartz, with a little galena, blende, and pyrite. Sheba Mine, Star district, Humboldt County, Nevada. (15591.)

(4) Massive, intimately mixed with galena, blende, and pyrite. A very characteristic specimen. Moose Mine, Park County, Colorado. (39411.)

CERARGYRITE (HORN SILVER.)

Composition: AgCl . Chloride of silver, containing silver, 75.3 per cent., and chlorine, 24.7 per cent.

It crystallizes in the isometric system, especially in cubes, octahedrons, dodecahedrons, and compounds of these. Its most general occurrence is massive, especially in crusts and flakes, and as the filling of minute fissures. It varies in hardness from 1 to 1.5, and in specific gravity from 5.31 to 5.55. When pure and perfectly fresh it is pearl-gray to colorless, but foreign material may give it a variety of tints, and on exposure to light it soon darkens in color and may become black on the surface. It has a resinous luster and may readily be cut with a knife, whence its name cerargyrite, which is the Greek equivalent of the common name horn silver.

Cerargyrite is one of the most important of all the silver minerals, and has yielded large amounts of the metal. It is generally the result of the decomposition of other silver minerals, and is therefore most abundant in the upper workings of a mine, above the water level. To illustrate the occurrence of cerargyrite seven specimens are shown:

(1) Imperfect crystals, resulting from the decomposition of ruby silver, in barite. Horn Silver Mine, Frisco district, Beaver County, Utah. (55337.)

(2) Crystallized, in quartz stained by decomposition products. High Bridge Mine, Philadelphia district, Nye County, Nevada. (15726.)

(3) Massive, with a little barite; a nearly solid lump of chloride of silver, weighing 10 pounds, and worth about \$100. Robert E. Lee Mine, Leadville, Lake County, Colorado. (5440.)

(4) A thin crust on quartz. Eberhardt Mine, Havana district, Madison County, Montana. (10928.)

(5) A crust on quartz. Meadow Valley Mine, Ely district, Lincoln County, Nevada. (15315.)

(6) Flakes, in decomposed material. High Bridge Mine, Philadelphia district, Nye County, Nevada. (15713.)

(7) Flakes, filling fissures in decomposed quartzose material. Barcelona Mine No. 1, Spanish-Belt district, Nye County, Nevada. (5832.)

EMBOLITE (MEGABROMITE.)

Composition: $\text{Ag}(\text{ClBr})$. Chloro-bromide of silver, in which the ratio of chlorine to bromine varies greatly, contains, silver 61 to 72 per cent., bromine 8 to 34 per cent., and chlorine 5 to 20 per cent.

It crystallizes in the isometric system, and occurs also massive and as coatings. It varies in hardness from 1 to 1.5, and in specific gravity from 5.31 to 5.43; is colored various shades of green and yellow; has an adamantine luster, and darkens on exposure to light.

Embolite frequently accompanies cerargyrite. To illustrate the occurrence of embolite one specimen is shown:

(1) Crystalline crust on chert. Robert E. Lee Mine, Leadville, Lake County, Colorado. (5442.)

SILVER ORES.

For the extraction of the metal, silver ores may be divided into two classes, milling ores and smelting ores; these again are subdivided into free-milling and roasting-milling, and silver-smelting, and silver-lead-smelting ores.

A milling ore is one from which the silver may be extracted by the use of mercury; a free-milling ore is one that yields its silver to mercury by simply crushing and submitting the fine material to the action of mercury, either with or without the aid of chemicals; a roasting-milling ore is one that requires roasting, generally with salt (chloridizing), before it will yield its silver to the mercury.

A smelting ore is one from which the silver can be extracted by fusion in a suitable furnace; a silver-smelting ore is one containing the silver mainly in the metallic state, and yields high grade bullion at one fusion, this character of ore is rare; a silver-lead-smelting ore is a lead ore containing silver, and which, on smelting, yields silver-lead or base bullion.

With the silver-lead-smelting ores are included the "dry" ores which require smelting to extract the silver but do not contain sufficient lead for that purpose. In smelting they are generally mixed with silver-lead-smelting ores containing an excess of lead or with silver-bearing copper ores.

There are a few ores that do not conform to this classification, but require different and more elaborate processes for the extraction of the metal; among these should be especially noted the leaching and the silver-bearing copper ores.

FREE-MILLING SILVER ORES.

Strictly speaking, only those ores containing silver in the metallic state or as chloride (iodide, bromide) can be called free-milling, since these are the only silver minerals that yield the metal easily to mercury; but by the use of various chemicals, especially sulphate of copper, other minerals, particularly the sulphide, can be made to yield the metal to mercury.

The gangue carrying the silver minerals varies greatly, pure and unaltered quartz, impure quartz, especially stained by decomposition products and containing oxides of several metals, particularly iron and manganese, and carbonates of lime and magnesia, calcite and dolomite, being the most common.

In some cases mines produce free-milling ores at all depths, where the characteristic ore from the lower levels is essentially quartz or calcite carrying free silver, argentite, and similar minerals. In a great many cases, however, a mine will produce free silver and chloride at and near the surface, or above the water level, from the decomposition of other silver minerals, and after passing the water level the charac-

ter of the ore will change and cease to be free milling. In some cases the ore simply becomes a roasting-milling ore; in some it may become a silver-lead smelting ore, and in others metals occur with the silver requiring a special treatment, while in others it may become so refractory that its silver can no longer be extracted to advantage.

In many cases ores that are called free-milling contain silver that will not amalgamate, and frequently in such cases the tailings from the process contains enough silver to be reworked by other processes. Sometimes ores containing the metal partly in a condition to amalgamate and partly not are treated as if none of it would amalgamate.

To illustrate the occurrence of strictly free-milling ores thirteen specimens are shown:

(1) Free silver, in fine wire and moss, and sulphides, especially galena and blende, in calcite. Santa Domingo Mine, Batopilas, Mexico. (64959.)

(2) Free silver, in a mass of black decomposition products, in quartz stained by iron and copper. Arizona Mine, Buena Vista district, Humboldt County, Nevada. (15620.)

(3) Silver and cerargyrite, in fossiliferous sandstone, the silver being more or less intimately associated with the fossils; commonly called silver-bearing sandstone. Rich ore. Barbee and Walker Mine, Silver Reef district, Washington County, Utah. (55322.)

(4) Cerargyrite, in small specks in siliceous sandstone. Rich ore. Stormont Mine, Silver Reef district, Washington County, Utah. (55333.)

(5) Cerargyrite, in thin but large flakes on limonite. Mount Diablo Mine, Columbus district, Esmeralda County, Nevada. (15637.)

(6) Cerargyrite, in small flakes scattered through quartz stained by decomposition products. Mineral Hill Mining Company, Mineral Hill district, Elko County, Nevada. (15325.)

(7) Siliceous limestone, containing the silver as cerargyrite. Eberhart and Aurora Mine, White Pine district, White Pine County, Nevada. (15660.)

(8) Limestone and quartz, showing stains of decomposition from copper minerals, containing the silver as cerargyrite. Eberhart and Aurora Mine, White Pine district, White Pine County, Nevada. (65317.)

(9) Limestone and quartz, showing stains of manganese; a frequent associate of free-milling ores. Eberhart and Aurora Mine, White Pine district, White Pine County, Nevada. (65318.)

(10) Quartz, stained by lead and iron decomposition products. Northern Belle Mine, Columbus district, Esmeralda County, Nevada. (15631.)

(11) Quartz, stained by lead and copper decomposition products. Brown's Hope Mine, Lida Valley district, Esmeralda County, Nevada. (15578.)

(12) Quartz, stained by lead decomposition products and containing a little galena; also stained by carbonate of copper. Star Mine, Mineral Hill district, Elko County, Nevada. (15326.)

(13) Quartz, stained by lead, copper, and iron decomposition products. Tipton Mine, Columbus district, Esmeralda County, Nevada. (15633.)

To illustrate free-milling ore requiring the use of chemicals, twelve specimens are shown:

(1) Quartz, containing sulphides more or less decomposed. Belmont Mine, Philadelphia district, Nye County, Nevada. (15366.)

(2) Quartz, containing sulphides more or less decomposed; showing stains of copper. Little Bonanza Mine, Cope district, Elko County, Nevada. (15817.)

(3) Quartz, stained by decomposition products, especially copper minerals. Belmont Mine, Philadelphia district, Nye County, Nevada. (15428.)

(4) Galena and tetrahedrite, showing decomposition. Highbridge Mine, Philadelphia district, Nye County, Nevada. (15439.)

All the following specimens are from the Comstock Lode, Storey County, Nevada :

(5) Free silver, argentite, stephanite, and other sulphides, with quartz, both characteristic and stained by decomposition products. Mexican Mine. (15463.)

(6) Argentite, in quartz, with other sulphides. Rich ore. Hale & Norcross Mine. (15202.)

(7) Various sulphides, especially argentite and sulph-antimonides of silver, in quartz. Rich ore. California and Consolidated Virginia Mine. (15364.)

(8) Various sulphides, especially argentite, pyrite, and chalcopyrite, in quartz. Rich ore. Crown Point Mine. (15223.)

(9) Quartz, milk white, imperfectly and coarsely crystallized in plates, with argentite deposited between the crystals. Very characteristic. Crown Point Mine. (65319.)

(10) Decomposed material and quartz, showing small amounts of sulphides. A good representative specimen. Consolidated Virginia Mine. (15191.)

(11) Quartz with some calcite, carrying sulphides. Average value \$70 per ton. A fair representative specimen. Belcher Mine. (15225.)

(12) Sulphides, argentite, galena, blende, chalcopyrite, with a little quartz. Rich ore. Ophir Mine. (15193.)

These Comstock ores contain on the average nearly 50 per cent. of their value in gold, but the relative amount of silver by weight exceeds the gold so much that they are classed as silver ores, and are treated by the milling process with the use of chemicals, and well illustrate this character of ores.

ROASTING MILLING ORES.

Where silver ores contain so much base metal, as lead or copper, especially in the form of sulphides, as to prevent the silver from amalgamating, and yet not enough to constitute a smelting ore, or when the silver is in a complex compound, such as the sulph-antimonides and arsenides, that will not amalgamate, they must be roasted before they will readily yield the metal to mercury. Occasionally a simple roasting is sufficient, but generally an addition of salt is required in order to convert the silver into chloride.

These ores generally occur in a quartzose gangue, and while this is occasionally stained by decomposition products it is frequently quite pure and unaltered. Sometimes carbonates, especially the carbonate of manganese, are abundant in the ore.

To illustrate the occurrence of roasting-milling ores five specimens, together with a complete series from the Ontario Mine, are shown.

(1) Free silver and argentite, in quartz, together with an intimate mixture of sulphides, several of which carry silver; also carbonate of manganese (rhodochrosite). Rich ore. Moulton Mine, Deer Lodge County, Montana. (55576.)

(2) Argentite, in quartz, together with an intimate mixture of sulphides, several of which carry silver; also carbonate of manganese (rhodochrosite). Moulton Mine, Deer Lodge County, Montana. (55561.)

(3) Various sulphides, especially galena, in quartz and rhodochrosite. Ordinary run of ore. Moulton Mine, Deer Lodge County, Montana. (55575.)

(4) Pyrargyrite and stephanite, in quartz. Rich ore. Grove's Mine, Reese River district, Lander County, Nevada. (15127.)

(5) Pyrargyrite and stephanite, in quartz, with various other sulphides, especially pyrite. Rich ore. The specimen shows the full width of the vein. Dollarhide Mine, Reese River district, Lander County, Nevada. (15136.)

THE ONTARIO MINE.

This mine is situated at Park City, Summit County, Utah, and is one of the model silver mines of the country, having been a constant producer of bullion since it was first opened in 1874, and being now well developed and prospected several years ahead of the actual mining.

The vein is a contact between a porphyry hanging wall and a quartzite foot wall, the latter dipping towards the vein. The vein proper is 10 to 45 feet thick, while the pay streak varies from 10 inches to 16 feet. It has been developed for a distance of 3,000 feet along the strike and to a depth of 1,000 feet. There are three three compartment shafts, two compartments being for the hoisting of ore and the other for pumps and pipes. Owing to the shattered and fissured nature of the foot wall the mine receives the drainage of a very large area, and is consequently very wet; 6,000 gallons a minute of water are pumped and drained from it.

The ore from the upper levels was free-milling, but as depth was gained it became more and more base from the increase of zinc, lead, and copper sulphide minerals, and all the ore required roasting with salt. At still greater depths galena, very rich in silver, appeared abundantly, and now considerable smelting ore is produced. Thus the mine furnishes an excellent illustration of the changes which take place in going down upon a vein.

The ore consists of quartz and sulphides, most of which are more or less decomposed; pyrargyrite, galena, blende, tetrahedrite, and carbonates of copper being readily discernable, while wulfenite and free sulphur are occasionally found. There is a considerable amount of clay, generally more or less stained by copper.

The collection from this mine was made by Captain Keith in October, 1884. It includes nineteen characteristic specimens taken over a large area of the mine, and is thoroughly representative.

The following specimen represents the general character of the vein:

(1) Galena, blende, tetrahedrite, pyrite, decomposition products. From 4th level, 670 feet west of drain tunnel. (55733.)

Five samples from different points on the fifth level west of drain tunnel show:

(1) Quartz, colored by various decomposition products, especially copper. 125 feet. (55726.)

(2) Decomposition products, in quartz. 400 feet. (55729.)

(3) Galena, decomposition products, especially copper, and quartz. 506 feet. (55730.)

(4) Decomposition products in quartz. 577 feet. (55731.)

(5) Foot wall. 647 feet. (55742.)

(1) Decomposition products, pyrite. From sixth level, 80 feet east of drain tunnel. (55725.)

(2) Galena, pyrite, blende, and decomposition products. From sixth level, 70 feet east of drain tunnel. (55724.)

A section of the vein on the sixth level, about 125 feet west of the drain tunnel, is illustrated by four specimens:

(1) Hanging wall, stained by copper and iron. (55738.)

(2) Hanging wall. (55739.)

(3) Quartz, stained by decomposition products, especially copper and manganese. (55727.)

(4) Foot wall. (55741.)

A section of the vein on the sixth level, about 1,400 feet west of the drain tunnel, is illustrated by six specimens:

(1) Hanging wall. (55740.)

(2) Galena, decomposition products. (55734.)

(3) Galena, blende, tetrahedrite, decomposition products. (55735.)

(4) Decomposition products, quartz. (55736.)

(5) Decomposition products. (55737.)

(6) Foot wall. (55743.)

(1) Galena, decomposition products. From the eighth level, 130 feet west of drain tunnel. (55728.)

SILVER SMELTING ORES.

These ores consist of free silver, generally in crystalline branching aggregates of immense size, with occasionally a small amount of argentite, in a gangue, generally of crystalline calcite, the silver amounting in some cases to two-thirds of the weight of the ore. Along with this very rich ore there is always a large amount of lower-grade ore requiring a very different mode of treatment. On account of the richness of these ores the actual amount produced is small compared with the amount of the poorer ores. One ton of the former may be worth more than 100 tons of the latter.

The rich ores are simply melted, generally on a cupel, with suitable fluxes, to remove the gangue and leave the pure silver behind. The most common flux is litharge or oxide of lead. When argentite occurs with the silver scrap iron is added to reduce the silver from it. In some cases metallic lead is added and has to be removed by cupellation after the separation of the gangue and metal.

These ores are seldom treated at the mine, but are generally shipped away and are treated at some central point whenever a sufficient amount has accumulated. Many Mexican and South American mines have produced large amounts of silver from this character of ore. Some mines, notably the Kongsberg, in Norway, produce a large amount of silver in the native state in considerable masses.

SILVER-LEAD-SMELTING ORES.

These ores are simply lead ores containing a valuable amount of silver. In most cases there are no physical characters to distinguish the argentiferous from the nonargentiferous lead ores; and since the process of smelting the lead is the same in both cases, they will be shown in the lead series.

PROCESSES OF EXTRACTING SILVER.

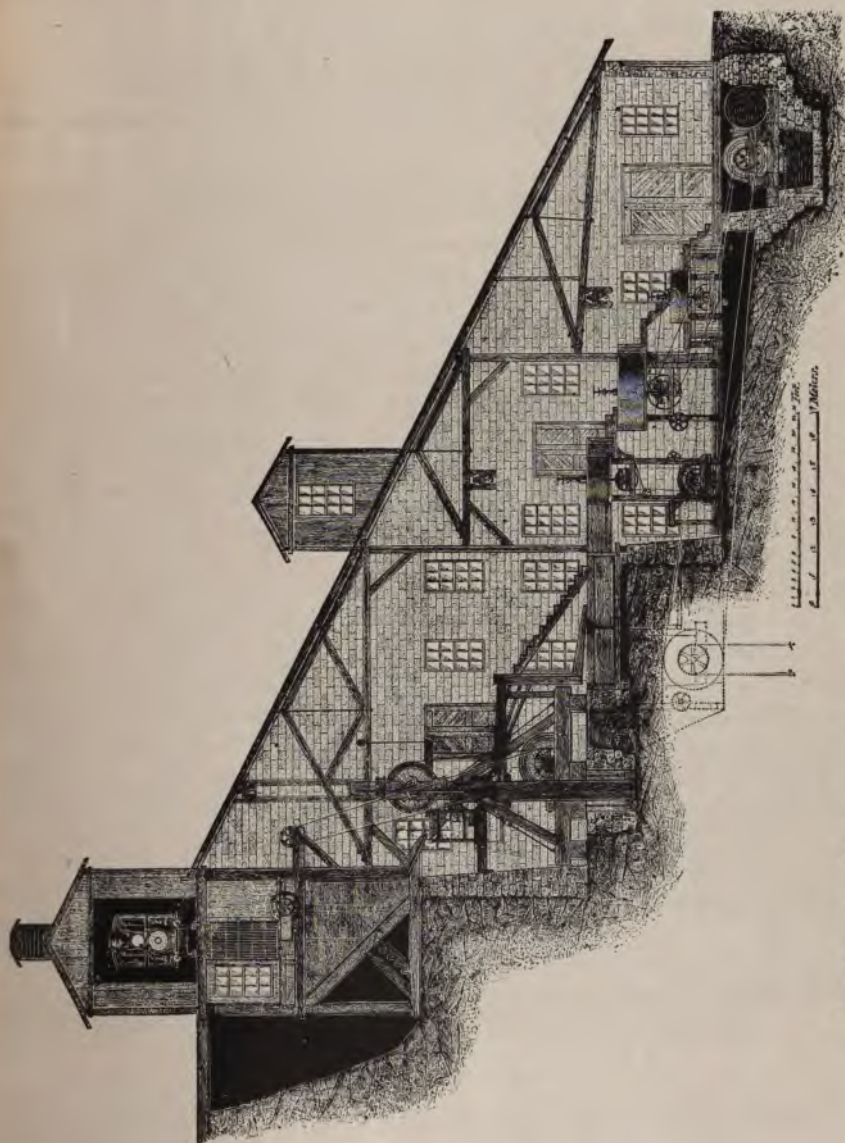
THE EXTRACTION OF SILVER FROM BASE ORES BY ROASTING AND MILLING.

The ore as delivered at the mills is first passed over a "grizzly," which is a screen of parallel bars, to separate the coarse from the fine. The coarse material is then passed through rock breakers to reduce it to a suitable uniform size. The fine ore from the grizzly and that from the breaker are passed on to some kind of a drying apparatus. After being thoroughly dried the ore is crushed, the fineness of the crushing depending on the character of the ore. The stamped ore is generally mixed with a certain proportion of dry stamped salt; in some cases, however, the salt is mixed with the ore previous to stamping. The amount of salt added to the ore varies according to circumstances, depending both upon the amount of silver in the ore and also upon the character of the gangue, rich ores requiring more salt and ores containing manganese requiring large amounts of salt.

The mixed ore and salt are next passed on to some kind of a roasting furnace, the object of the roasting being to transform the silver into chloride by means of the salt. Owing to the fineness of the material a considerable amount is carried out of the furnace by the draft, and this is collected as far as possible in dust chambers and flues, the material so collected being added from time to time to the product of the furnace.

After roasting the material is withdrawn from the furnace and allowed to remain in heaps in order to complete the chloridizing of the silver, after which it is transferred to the pans. In the pans a suitable amount of water is added to make a thin paste and sufficient mercury to gather the silver into an amalgam. Sometimes chemicals are also added in the pan, but this should be avoided as far as possible, and generally can be, by giving sufficient attention to the roasting. A thoroughly roasted ore should require no treatment in the pan. The use of a small amount of zinc in the pan is quite common and serves to protect the iron of which the pans are made.

By suitable arrangements the pulp in the pans is kept agitated, in order to bring the mercury into the closest contact possible with the ore; at the same time the ore is ground still finer. This operation is continued until as much as possible of the silver has combined with the mercury.



ELEVATION OF A MILL FOR THE CHLORIDIZING-ROASTING, AND AMALGAMATION OF SILVER ORES.
(See explanation, page XII.)

After the amalgamation is complete the material is run out from the pans into settlers, which are similar to the pans, except that they do not grind. In these the pulp is made much thinner by the addition of water, and the agitation of the material is so graduated as to keep the fine light ore in suspension, and to allow the heavy amalgam and mercury to sink to the bottom.

From time to time the water holding the waste material in suspension is drawn off at the top, and the amalgam and excess of mercury from the bottom. After leaving the mill the water carrying the tailings, or waste material, is allowed to deposit the tailings, which soon accumulate in large amounts.

The object of the whole operation is to remove as much as possible of the silver, so that these tails will be worthless. They are never entirely free from silver, and in some cases, owing to the bad working of the mill from various causes, or to a special rebelliousness of the ore, they have to be run through the mill again. In some cases, while yet containing a considerable amount of silver, they are allowed to accumulate until they can be treated more cheaply.

The amalgam from the settlers is thrown into stout canvas bags, which retain the amalgam, but allow the excess of mercury to strain through; this mercury is then ready to be used over again. The hard dry amalgam remaining in the strainers is collected, put into cast-iron retorts, and heated to drive off the mercury, which is collected and is ready for use again. The silver sponge or bullion remaining in the retort is melted in crucibles, and cast into ingots of suitable size.

The fineness or amount of silver in 1,000 parts of this bullion varies greatly, and depends upon the character of the ore, since the other metals found associated with the silver are affected more or less in the same way as the silver, and follow along through the whole operation with it, and are found in the bullion. This impure bullion has to be subjected to a refining operation in order to separate the silver, this, however, is generally carried on at a separate works, and especially at the mints.

A cross-section of a mill suited to this operation is shown in PL. III and the interior of a pan mill for extracting the silver by amalgamation in PL. IV.

To illustrate this operation two collections are shown. The first is from the Ontario Mill, Park City, Summit County, Utah, and the second from the Moulton Mill, Butte, Silver Bow County, Montana.

THE ONTARIO MILL.

This mill treats only the ores extracted from the Ontario mine. The ores from the Ontario mine, in the upper levels, consist of entirely decomposed material, being quartz stained by decomposition products, but in the lower levels unaltered sulphides make their appearance, especially galena, blende and tetrahedrite. Imbedded in the compact

galena will frequently be found patches of pyrargyrite, hardly to be distinguished from the galena, except by the closest inspection. The lump galena is very rich in silver, averaging about 200 ounces per ton, select specimens running as high as 800 to 900 ounces per ton. The average amount of lead in the ore is 2 per cent. The average amount of silver in the ores treated is about 100 ounces per ton, of which 96 per cent. is saved in the mill, 3 ounces remain in the tailings, and 1 ounce is lost in the treatment.

In this mill the ore and salt are dried in revolving dryers and stamped separately, the ore passing a No. 30 screen, and the salt a No. 16.

There are 80 ore stamps weighing 860 pounds each, making 96 drops of about 8 inches per minute, crushing 65 to 75 tons per 24 hours. There are 10 salt stamps weighing 430 pounds, making 94 drops per minute. By means of an automatic discharge the proper percentage of the dry stamped salt is added to the dry stamped ore as it is being elevated in buckets from the stamps to the top of the roasting furnace.

The roasting furnace, of the Stetefeldt pattern, is a plain square stack, 46 feet 6 inches high, 8 feet square at the bottom and 4 feet square at the top. At one side of the stack is a fireplace for wood and the flame from this fire passes into and through the stack. Near the top of this main stack a return flue 3 feet square, heated by an auxiliary fire, leads to a series of dust chambers. The mixed ore and salt are delivered to the top of the stack into an oscillating sieve, which sifts the material into the furnace. It takes about two minutes for the material to fall from the top, through the flame, to the bottom. This heating sets up the reactions necessary to convert the silver into the form of chloride, and the reaction continues after the material has passed through the flame. The roasted ore is allowed to collect in the bottom of the furnace, and of the return flue, and is withdrawn from time to time, about twice as much being taken from the latter as the former; it is then allowed to remain about 16 hours on the floor of the furnace house in order to complete the chloridizing. At longer intervals the material collected in the dust chambers is added to the piles of roasted ore from the two stacks on the floor.

The roasted ore is now taken to the pan house and mixed with hot water in the pans, which are 5 feet diameter and 3 feet high. A charge consists of 2,800 pounds of ore and 350 pounds of mercury, to which a small amount of granulated zinc is added. The agitator is revolved about sixty-five times a minute, and in about 8 hours the amalgamation is complete. After the amalgamation the material is run into the settlers and more water added. The settlers are 8 feet in diameter and 4 feet high, and the agitator makes 14 revolutions per minute. In about 4 hours the amalgam settles, so that the first portion of water can be run off; more water is then added, and the washing continued for about 4 hours more, so that the settlers will be ready for the next charge from the pans.



INTERIOR OF A PAN MILL, COMSTOCK LOPE, NEVADA.
(See explanation, page XII.)

From the settler the pulp passes through two agitators 9 feet in diameter and 4 feet high, running at eleven revolutions per minute. In these a small amount of amalgam that has been carried away mechanically during the washing is saved; from the agitators the pulp passes to the tailings dump.

The amalgam is taken from the settlers, cleaned and retorted. The retorts hold about 200 pounds of amalgam, and it requires about 8 hours to distill the mercury. The bullion from the retort is melted and cast into bars weighing about 100 pounds, eight bars per day being the products of the works. The bullion is from 600 to 800 fine.

The collection was made by the writer with the assistance of Mr. J. E. Gallagher, the superintendent of the mill, in September, 1884, and includes five samples of the lump ore, a sample of the material passing through the grizzly, and a sample of the ore from the rock crusher, the dried and stamped ore, the dried and stamped salt, the mixed ore and salt, a full series of roasted ore and flue dusts, the mercury and amalgam, the bullion and a model ingot. The exterior of the mill is shown in PL. V.

STAMP MILL SAMPLES.

Ore.

- (1) Quartz, stained by decomposition products, showing especially manganese and a little copper. (11476.)
- (2) Decomposition products, containing lead salts, showing stains of copper and manganese. (55732.)
- (3) Decomposition products and quartz, showing slight stains of copper and manganese. (55696.)
- (4) Galena and blende, in chert. (55697.)
- (5) Galena, containing ruby silver. (55695.)
- (6) An average sample of what passes through the grizzlies. (55700.)
- (7) Crushed, as it comes from the breaker. (55701.)
- (8) Dried, after passing through the hot cylinders. (55702.)
- (9) Stamped. (55703.)

Salt.

- (1) Used for chloridizing, obtained by solar evaporation of the water of Great Salt Lake, Utah. (55704.)
- (2) Dried and stamped, ready for mixing with the ore. (55705.)

Furnace charge.

- (1) Ore carrying 105 ounces of silver, mixed with 17 per cent. of salt, ready for charging into the Stetefeldt furnace. (55706.)

FURNACE SAMPLES.

Roasted ore.

- (1) From main stack of Stetefeldt furnace. (55707.)
- (2) From return flue of Stetefeldt furnace. (55708.)

Flue dust.

- | | |
|------------------------------|---------------------------------|
| (1) First chamber. (55709.) | (7) Seventh chamber. (55715.) |
| (2) Second chamber. (55710.) | (8) Ninth chamber. (55716.) |
| (3) Third chamber. (55711.) | (9) Tenth chamber. (55717.) |
| (4) Fourth chamber. (55712.) | (10) Eleventh chamber. (55718.) |
| (5) Fifth chamber. (55713.) | (11) Twelfth chamber. (55719.) |
| (6) Sixth chamber. (55714.) | |

MILL SAMPLES.

- (1) Mercury, used in the pan to amalgamate the silver. (51117.)
- (2) Silver amalgam, taken from the strainer. (55720.)
- (3) Tailings, containing three ounces of silver per ton; thrown away as waste. (55723.)
- (4) Silver bullion, about 700 fine. (55721.)
- (5) Model of ingot No. 11998, containing 1,551.50 ounces of bullion 646 fine. (55722.)

MOULTON MILL.

The process followed is the same as at Park City, but it varies in its details, partly on account of the general difference in the character of the ores treated, and partly because ores from different mines with varying characters are treated. The Moulton ores carry their silver in the form of native silver, argentite, and ruby silver, together with argentiferous sulphurets. The main difference between the two ores being the large percentage of pyrite and manganiferous minerals, and smaller percentage of blende in the Moulton ores. In the ores from the lower levels, the carbonate of manganese (rhodochrosite) is quite abundant, but in the upper levels this has been altered to various oxides of manganese, which consume and waste large amounts of salt in the roasting operation.

In the mill the ore and salt are mixed before drying, and are then spread over hot plates to dry; after drying they are stamped and roasted. The roasting takes place in a revolving cylinder of the Howell pattern; this consists of a hollow iron cylinder lined with firebrick, set at an angle and slowly revolved. The ore is fed into the cool end, as it descends toward the hot end successive portions are exposed to the action of the flames, and in this way the roasting is accomplished. A much larger portion of the ore passes through the furnace than in the Stetefeldt roaster, consequently less fine ore is carried off by the draft, and fewer chambers are required to catch the dust. At the Moulton mill some of the dust chambers are emptied only at long intervals. After roasting the ores are allowed to stand from three to five days on the floor, and from that stage of the process until the melting of the bullion the process is the same as at the Ontario mill.

The collection was made by the writer with the assistance of Mr. J. K. Clark, general superintendent, in September, 1884, and includes—



EXTERIOR OF THE ONTARIO MILL, PARK CITY, SUMMIT COUNTY, UTAH.
(See explanation, page XII.)

*STAMP MILL SAMPLES.**Ore.*

- (1) Free silver and argentite, on crystallized quartz, with a little pyrite. Very rich specimen. (65146.)
- (2) Various sulphides, in quartz. (55560.)
- (3) Galena and blende, in quartz, with a little rhodochrosite. (55561.)
- (4) Pyrite and chalcopyrite, in crystals, with galena and blende, in quartz. (55562.)
- (5) Surface ore, showing large amounts of oxides of manganese. From the Nonesuch mine. (55564.)
- (6) Average sample of the lump ore, showing sulphides in quartz and rhodochrosite. (55563.)

Salt.

- (1) Used for chloridizing, obtained by solar evaporation of the water of Great Salt Lake, Utah. (55565.)

Furnace charge.

- (1) Consisting of ore containing 55 to 60 ounces of silver, and salt, stamped together. (55566.)

*FURNACE SAMPLES.**Roasted ore.*

- (1) From Howell roaster. (55567.)

Flue dusts.

- (1) First chamber. (55568.)
- (2) Second chamber. (55569.)
- (3) Third chamber. (55570.)
- (4) Fourth chamber. (55571.)
- (5) Main flue, 100 feet from fourth chamber. (55572.)

MILL SAMPLES.

- (1) Mercury, used in the pans to amalgamate the silver. (55573.)
- (2) Silver amalgam, taken from the strainer. (55574.)
- (3) Silver bullion, from the retort. (55836.)

THE ZIERVOGEL PROCESS.

This is an exceedingly interesting compound process for the treatment of argentiferous copper ores, and is frequently modified so as to include gold ores. Frequently, also, gold and silver ores free from copper are used in the process, the gold and silver in them being gathered and concentrated by means of the copper in the copper ores. The process depends upon the fact, that when a mixture of sulphide of iron, copper, and silver, such as an ordinary argentiferous copper matte produced by a series of preliminary roasting fusions, is exposed to the action of air at the proper temperature the iron is readily converted into sulphate, at a somewhat higher temperature this will decompose, giving

off sulphuric anhydride, and sulphate of copper will be formed, at a still higher temperature this will decompose, giving off sulphuric anhydride, and sulphate of silver will be formed. Sulphate of silver being soluble in water, while the oxides of iron and copper, formed by the decomposition of the sulphates, are insoluble, it can be readily leached out by warm water.

Metallic silver can be precipitated from the solution of silver sulphate by letting it flow over metallic copper plates. The residues are frequently treated a second time for silver, and if the ores contain gold they are always treated for the recovery of this metal, after which the copper is recovered by smelting. The copper in the solution after precipitating the silver is precipitated by scrap iron.

Boston and Colorado Smelting Works.—The Ziervogel process is illustrated by a collection from the Boston and Colorado Smelting Works situated at Argo, near Denver, Colorado. They were built chiefly for the purpose of extracting silver and copper from argentiferous copper ores, but the process has been extended so as to include gold ores in the treatment. The works are so situated that they can draw their supplies from an extended area of country, and thus command a large variety of ores, and especially refractory ores.

Besides the strictly argentiferous copper ores for which the Ziervogel process was devised, many rebellious ores, especially those containing zinc, which can not be readily treated in any other way, and in fact almost any gold or silver ore, except those containing large amounts of lead, are treated successfully. This treatment of rebellious ores is rendered possible by having a good supply of docile ores for mixing.

Ores consisting essentially of sulphides are first roasted to remove the excess of sulphur. Lump ores are roasted in kilns and the sulphur reduced to 7 per cent. Fine ores are roasted in reverberatory furnaces and the sulphur reduced to 5 per cent. The roasted ores are mixed with raw ores not requiring roasting, and the mixture smelted in a reverberatory furnace for the production of matte. The ore mixture is made up so that 16 tons will produce 1 ton of matte of the following composition:

<i>Matte.</i>		Per cent.
Copper (Cu)		38. 78
Lead (Pb)		24. 52
Iron (Fe)		7. 49
Zinc (Zn)		3. 42
Manganese (Mn)		0. 32
Silver (Ag)		2. 48
Gold (Au)		0. 05
Antimony (Sb)		0. 08
Sulphur (S)		22. 26
Insoluble residue		0. 46

The earthy impurities of the ore form a slag of the following composition :

<i>Slag</i>	Per cent.
Silica (SiO_2)	39.70
Alumina (Al_2O_3)	5.71
Protoxide of iron (FeO)	31.26
Protoxide of manganese (MnO)	4.00
Oxide of lead (PbO)	3.66
Lime (CaO)	2.54
Magnesia (MgO)	0.07
Sulphur (S)	0.75
Copper (Cu)	0.30

The specific gravity of this slag varies from 3.6 to 3.8, but occasionally, especially when lead is absent, it falls as low as 3.4. The slag from each charge is drawn off as soon as the charge is thoroughly smelted, but the matte is allowed to accumulate in the furnace, and is drawn off once in 24 hours. The slag drawn off towards the end of the skimming frequently contains shot of matte, and it is therefore returned to the furnace, as are also abnormal slags which are rich in metal.

This first matte is mixed with rich siliceous silver ores, and subjected to a second fusion for the production of concentrated matte. This second matte is coarsely crushed and roasted, it is then ground very fine and roasted again for the production of sulphates. This sulphate roasting is carried just as far as possible, in order to convert all or nearly all the silver into sulphate, but it must be stopped before all the sulphate of copper has been decomposed, since the last traces of sulphate of copper can not be decomposed without decomposing a portion of the sulphate of silver, which would render the silver insoluble in water. The sulphate of iron first formed is completely decomposed during the latter stage of the operation.

The product of this roasting is leached in vats with hot water, which dissolves the sulphate of silver. This solution is allowed to run over plates of copper which precipitate the silver, and after depositing the silver, the solution flows over scrap iron, which removes both the copper dissolved out of the ore as sulphate, and also that which was dissolved in precipitating the silver. The precipitated metallic silver is thoroughly washed, dried, and melted, and then cast into bars.

The residues left after dissolving out the sulphate of silver are mixed with rich sulphide and telluride gold ores and smelted ; this gives a rich matte containing gold and silver. It is subjected to a second smelting, which gives copper bottoms containing the gold, and pimple metal containing the silver ; this latter is roasted for sulphate of silver in the same manner as the concentrated matte, and the residues from this process are smelted for the production of copper,

The operation of the process is illustrated by the following scheme figure 2:

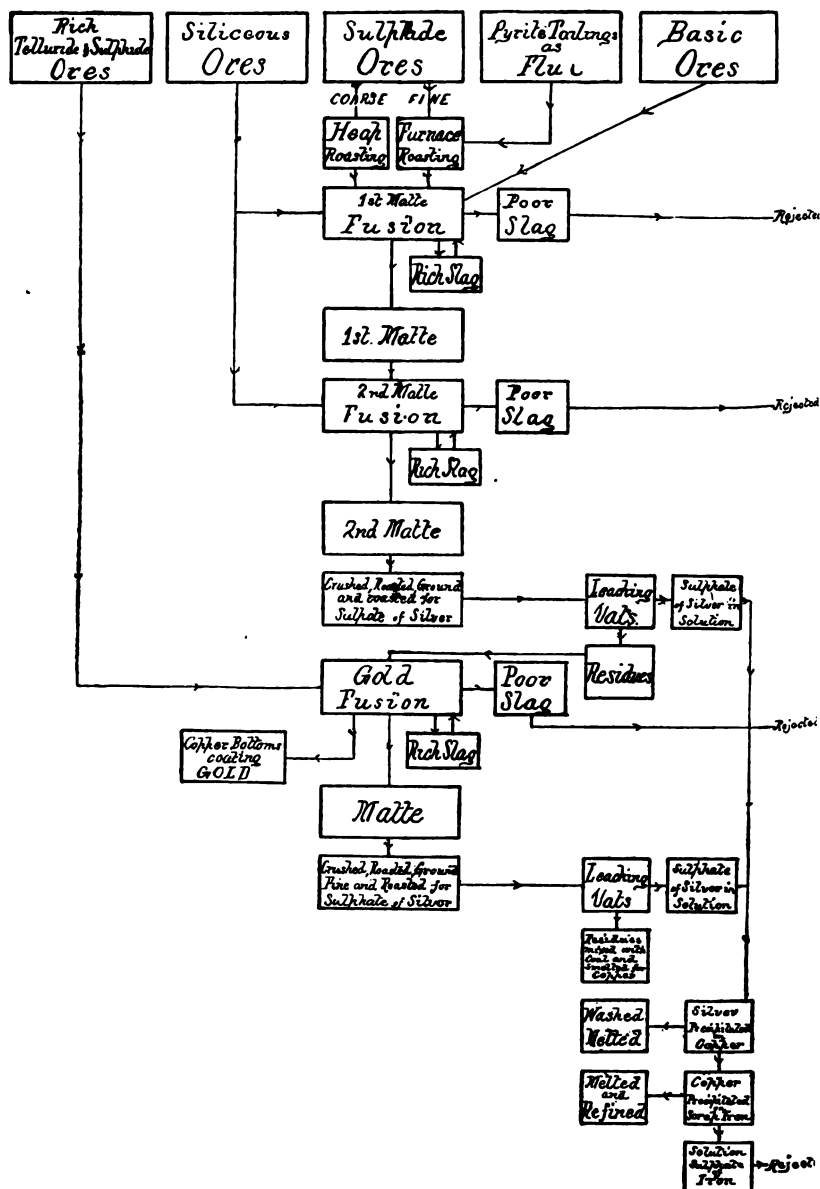


FIG. 2.
Scheme showing Ziervogel process.

The collection was prepared by Mr. Richard Pearse, metallurg of the works and shows a full series of the ores treated and each step the operation.

ORES.

True Ziervogel ores.

(1) Basic sulphide ore, chalcopyrite showing some decomposition, with a little quartz. Contains 30 ounces of silver per ton and 20 per cent. of copper. Gunnison, County, Colorado. (55947.)

(2) Basic oxidized ore, impure silicate of copper. Contains 50 ounces silver per ton and 30 per cent. of copper. New Mexico. (55952.)

(3) Siliceous ore, quartz stained by decomposition products and containing some unaltered sulphides. Contains 50 ounces silver per ton and 6 per cent. of copper. Montana. (55955.)

Ziervogel ores containing gold.

(1) Basic sulphide ore, tetrahedrite, chalcopyrite, galena, and quartz. Contains 2 ounces gold, 100 ounces silver per ton, and 10 per cent. of copper. Gunnison County, Colorado. (55946.)

(2) Basic sulphide ore, pyrite, chalcopyrite, with a little quartz. Contains 5 to 10 ounces gold, 20 ounces silver per ton and 5 per cent. of copper. Gilpin County, Colorado. (55949.)

(3) Siliceous ore, quartz containing tetrahedrite and stained by salts of copper. Contains 1 ounce gold, 20 ounces silver per ton and 6 per cent. of copper. Utah. (55956.)

Siliceous ores for mixture with first matte in the fusion for second matte.

(1) Iron-stained quartz. Contains 50 to 100 ounces of silver per ton. Robert E. Lee Mine, Leadville, Lake County, Colorado. (55944.)

(2) Quartz, with a small amount of sulphides. Contains 50 to 100 ounces of silver per ton. Clear Creek County, Colorado. (55950.)

(3) Quartz, stained by decomposition products. Contains 50 to 100 ounces of silver per ton. Gilpin County, Colorado. (55951.)

Complex and refractory ore.

(1) Basic sulphide ore, galena, blende, and pyrite. Contains 50 ounces of silver per ton. Robinson Mine, Colorado. (55943.)

Rich sulphuretted gold ores for mixture with leached residue for fusion.

(1) Siliceous ore, chert mixed with sulphides and tellurides; very complex ore. Contains 5 to 10 ounces of gold, and 100 to 500 ounces of silver per ton. Bassick Mine, Rosita, Custer County, Colorado. (55945.)

(2) Siliceous ore, quartz with some sulphides. Contains 5 to 10 ounces of gold and 20 to 50 ounces of silver per ton. Boulder County, Colorado. (55948.)

Basic ores, valuable on account of their fluxing properties.

(1) Oxide of manganese and quartz, concentrates. Contain 50 to 100 ounces of silver per ton. Silver Cliff Mine, Rosita, Custer County, Colorado. (55954.)

(2) Sulphide ore, pyrite and chalcopyrite, concentrated from the gold ores of Gilpin County, Colorado. Contains 1 ounce of gold and 3 ounces of silver per ton. (55953.)

(3) Roasted sulphide ore, No. 55953, roasted in reverberatory furnace. (55958.)

(4) Roasted ore, a mixture of Nos. 55943 and 55955. (55957.)

FURNACE SAMPLES.

First fusion.

(1) Furnace charge, mixture of the ores as prepared for the first smelting for matte. (55959.)

(2) First matte, produced by smelting the ore mixture, No. 55959. Contains 48 per cent. of copper. (55963.)

- (3) Clean slag, from the first smelting for matte. (55961.)
- (4) Clean slag, crystallized. (55960.)
- (5) Slag, coated with moss copper. (55962.)

Second fusion.

- (1) Furnace charge, mixture of first matte with rich siliceous silver ores. (55964.)
- (2) Second matte, produced by smelting No. 55964. Contains 60 per cent. of copper. (55965.)
- (3) Matte, containing 50 per cent. of copper, similar to No. 55965, but produced by a single fusion at the Boston and Montana Smelter, Butte, Montana. (55966.)

Ziervogel process.

- (1) Second matte, roasted and ground, ready for fine roasting for the production of sulphate of silver. (55967.)
- (2) Silver, precipitated on copper plates from solution of sulphate of silver from No. 55967, after roasting for sulphate. (55969.)
- (3) Residue, after leaching out sulphate of silver. (55968.)

Third fusion.

- (1) Furnace charge, mixture of leached residues with rich sulphureted gold ores. (55970.)
- (2) Matte, from smelting No. 55970. (55971.)

Copper fusion.

- (1) Pimple metal, from treatment of No. 55971. Contains 75 per cent. copper and 100 ounces of silver per ton. (55972.)
- (2) Pimple metal, calcined and ground. (55973.)
- (3) Oxide of copper. Contains 90 per cent. of copper. (55974.)

LEAD.

LEAD MINERALS.

GALENITE. (GALENA.)

Composition : PbS. Sulphide of lead, containing lead 86.6 per cent. and sulphur 13.4 per cent.

It crystallizes in the isometric system, especially in cubes with modifying faces. Its most common occurrence is crystalline granular, varying from impalpable to very coarse. One of its most marked characters is its perfect cubic cleavage, which shows distinctly whenever a piece is broken, and frequently makes it very friable. It varies in hardness from 2.5 to 2.75, and in specific gravity from 7.25 to 7.7, has a lead-gray color and full metallic luster, occasionally tarnishes, and sometimes shows iridescent colors on the surface.

Galenite is the most common and abundant of the lead minerals and is undoubtedly the original lead mineral. Wherever exposed to decomposing influences it changes rapidly and frequently occurs coated with its decomposition products, since they are mostly insoluble.

All galenite contains more or less silver, and frequently in our Western States the silver is the most valuable constituent. The amount of silver required to render a galena ore sufficiently argentiferous to be called an ore of silver varies greatly, depending on the circumstances of its occurrence. It also frequently contains gold, sometimes visibly, and generally contains, even in the purest specimens, small amounts of other sulphides. To illustrate the occurrence of galena five specimens are shown.

(1) A single large and distorted cube with small octahedral faces. Mine La Motte, Madison County, Missouri. (17137.)

(2) Crystallized, an aggregate of cubes with octahedral faces. Joplin Mine, Joplin, Jasper County, Missouri. (17590.)

(3) Crystallized, separate cubes with octahedral faces on dolomite. Seed Lick Diggings, Mine La Motte, Madison County, Missouri. (17126.)

(4) Crystallized, single cubes with small octahedral faces. All the faces have a thin coating of pyrite. Joplin, Jasper County, Missouri. (17592.)

(5) Massive, showing the cubic cleavage in perfection. Missouri. (65268.)

Many massive specimens of galena may be seen in the silver-lead ore series.

ANGLESITE.

Composition: PbSO_4 . Sulphate of lead, containing oxide of lead 73.6 per cent. (lead 68.4 per cent.), and sulphuric acid, 26.4 per cent.

It crystallizes in the orthorhombic system, crystals being complex, and frequently tabular or octahedral in habit, occasionally occurs stalactitic and sometimes massive. It varies in hardness from 2.75 to 3, and in specific gravity from 6.12 to 6.39. It has an adamantine luster and is colorless or slightly tinged and transparent.

Anglesite is generally associated with, and is the result of, the decomposition of galena, when, however, it has been subjected to the action of carbonated waters it is readily changed to the carbonate of lead, cerussite. It is always more abundant in the upper levels of a mine. To illustrate the occurrence of anglesite three specimens are shown.

(1) Transparent white crystals, on galena. Elkhead, Christian County, Missouri. (64283.)

(2) Transparent white crystals, in a cavity in galena. Modoc Mine, Leadville, Lake County, Colorado. (56446.)

(3) Massive, showing the cubic outlines of the original galena. Madonna Mine, Monarch, Chaffee County, Colorado. (51539.)

In the collection from the Colorado smelter may be seen several specimens of anglesite associated with both unaltered galena and cerussite.

CERUSSITE. (WHITE LEAD ORE.)

Composition: PbCO_3 . Carbonate of lead, containing oxide of lead 83.5 per cent. (lead 77.5 per cent.), and carbonic acid 16.5 per cent.

It crystallizes in the orthorhombic system, crystals usually thin, tabular, and very frequently twinned, often found granular, and sometimes

massive. It varies in hardness from 3 to 3.5, and in specific gravity from 6.46 to 6.48. It has an adamantine luster and is colorless or tinged, generally by salts of copper, and is transparent.

Cerussite is generally associated with, and is the result of the decomposition of galena, its formation generally being subsequent to that of anglesite. It is much more common than the sulphate. It is always more abundant in the upper levels of a mine. To illustrate the occurrence of cerussite six specimens are shown.

(1) Crystallized, separate transparent tabular crystals on galena. Potosi, Washington County, Missouri. (4182.)

(2) Crystallized, aggregates of small crystals encircling galena. Miller Mine, American Fork district, Salt Lake County, Utah. (18051.)

(3) Crystallized, aggregates of slightly coherent crystals. Cave Mins, Milford, Utah. (56034.)

(4) Crystallized, coarse sand of crystals. Utah. (11502.)

(5) Crystallized on massive, colored a little by iron. Yosemite Mine, Bingham Canyon, Utah. (55929.)

(6) Massive. Florence Mine, Leadville, Lake County, Colorado. (56432.)

Many more specimens, both crystallized and massive, will be found in the silver-lead ore series.

SILVER-LEAD ORES.

The silver-lead ores consist of the various lead minerals carrying sufficient silver to render its extraction profitable, as in the case of all other ores. The amount of silver in a lead ore that will render its extraction profitable varies greatly with circumstances. As low as 10 ounces of silver in an ore containing a high percentage of lead may, under favorable circumstances, be profitably smelted. In a large majority of cases there are no distinct silver minerals to be observed in these ores, the silver simply replacing the lead in the compound. In a few cases, however, distinct silver minerals have been found, especially where the original galena has undergone complete decomposition. In some cases large masses of chloride of silver have thus been segregated, as in the case of the Robert E. Lee Mine, of Leadville, Colorado; while in others the silver exists in such a condition that a portion of it, at least, will amalgamate. Some of the surface ores at Leadville were treated by amalgamation.

At the present time large amounts of both lead and silver are produced from ores of this character, and it is only under the most favorable circumstances that nonargentiferous lead ores can be smelted.

Galena is frequently associated with other sulphides that are more or less argentiferous, and occasionally auriferous; the most common of these is the sulphide of zinc (blende). When the lead is undergoing decomposition the other sulphides decompose also; and whether the products of decomposition remain with the lead or are carried away depends upon whether the decomposition product formed is soluble or not. In the case of blende, the decomposition products generally are soluble; and where mixtures of galena and blende have undergone de-

composition, the lead decomposition products are generally quite free from zinc.

The collection to illustrate silver-lead ores begins with galena (the original lead mineral) as pure as possible, and shows its different modes of occurrence; it is then followed on through increasing impurities to the commencement of decomposition, and this is followed through until we have as the final state the carbonate of lead (cerussite).

(1) Galena, in rough crystals, showing the characteristic cubic cleavage in great perfection. Old Story Mine, Georgetown, Clear Creek County, Colorado. (65305.)

(2) Galena, showing coarse cubic cleavage. Washington Mine, South Mountain district, Owyhee County, Idaho. (14817.)

(3) Galena, showing coarse cleavage, with a little pyrite. North Pacific Mine, Ten-Mile district, Lewis and Clarke County, Montana. (10896.)

(4) Galena, showing medium cleavage. Belle of Belleville Mine, Colorado district, Jefferson County, Montana. (10886.)

(5) Galena, a mixture of fine and coarse cleavage, showing also a little blende. Moose Mine, Park County, Colorado. (39613.)

(6) Galena, showing fine cleavage, with a little pyrite. Cañon Mine, Lump Gulch district, Jefferson County, Montana. (10902.)

(7) Galena, showing fine cleavage. Yosemite Mine, Bingham, Salt Lake County, Utah. (18000.)

(8) Galena, showing fine-grained cleavage, also a beautiful tarnish. Consolidated Gregory Mine, Colorado district, Jefferson County, Montana. (10912.)

(9) Galena, showing very fine cleavage. Argentine Mine, Colorado district, Jefferson County, Montana. (10887.)

(10) Galena, blende, and pyrite, with a little quartz. Keystone Mine, Park County, Colorado. (39773.)

(11) Galena, with much blende and a little pyrite. Hiawatha Mine, Chaffee County, Colorado. (36679.)

(12) Galena and pyrite. Grecian Bend Mine, Bingham, Utah. (14715.)

(13) Galena, with much pyrite and a little chalcopyrite. Buckhorn Mine, Carlisle district, Boulder County, Colorado. (19131.)

(14) Galena, with a little blende and some pyrite. Idaho Mine, Boulder County, Colorado. (39497.)

(15) Galena, blende, and quartz. Hercules and Roe Mine, Clear Creek County, Colorado. (39790.)

(16) Galena, blende, and quartz, with a little pyrite and tetrahedrite. Hiawatha Mine, Chaffee County, Colorado. (39690.)

(17) Galena, with a little pyrite and blende, in quartz. Hathaway Mine, Potosi district, Madison County, Montana. (11048.)

(18) Galena, in quartz with barite. Mammoth Mine, Hot Springs district, Jefferson County, Montana. (10997.)

(19) Galena, showing coarse cleavage, beginning to decompose. First National Mine, Stockton, Tooele County, Utah. (14744.)

(20) Galena, showing fine cleavage, beginning to decompose. Little Chief Mine, Leadville, Lake County, Colorado. (32496.)

(21) Galena, showing decomposition products, including crystals of gypsum on the outside. First National Mine, Rush Valley district, Tooele County, Utah. (14647.)

(22) Galena, showing decomposition products stained with iron. Miller Mine, American Fork district, Salt Lake County, Utah. (65370.)

(23) Galena, with a little pyrite, showing decomposition products. Richmond Mine, Eureka district, Eureka County, Nevada. (15530.)

(24) Galena, showing decomposition products. Kempton and Neptune Mine, Bingham Cañon, West Mountain district, Salt Lake County, Utah. (18065.)

- (25) Galena and pyrite, showing decomposition products, including stains of copper. Ohio Mine, Little Cottonwood district, Salt Lake County, Utah. (14735.)
- (26) Galena, crystallized, showing decomposition products, especially copper. Rebellion Mine, Pinyon Hill district, Summit County, Utah. (55351.)
- (27) Galena, showing much decomposition, with heavy stains of copper. Rebellion Mine, Pinyon Hill district, Summit County, Utah. (55346.)
- (28) Galena, much decomposed to cerussite, pyrite, and carbonates of copper. Neptune Mine, West Mountain district, Salt Lake County, Utah. (30065.)
- (29) Galena, much decomposed, showing crystals of cerussite. Rollins Mine, Lincoln district, Beaver County, Utah. (14672.)
- (30) Galena, much decomposed. Speckled Trout Mine, Flint Creek district, Deer Lodge County, Montana. (11092.)
- (31) Galena, much decomposed, showing crystals of gypsum. Treasure Hill, White Pine County, Nevada. (15281.)
- (32) Galena, showing decomposition through the sulphate to the carbonate and retaining the outlines of the original galena. Hidden Treasure Mine, Ophir district, Utah. (11541.)
- (33) Galena, showing decomposition through the sulphate to the carbonate and retaining the outlines of the original galena; shows crystals of sulphur on the outside. Horn Silver Mine, Frisco district, Beaver County, Utah. (55339.)
- (34) Galena, almost entirely decomposed and retaining the outlines of the original galena. Comet Mine, Boulder district, Jefferson County, Montana. (10963.)
- (35) Cerussite, surrounding a small lump of unaltered galena. Raymond & Ely Mine, Ely District, Lincoln County, Nevada. (15305.)
- (36) Cerussite, surrounding a very small lump of unaltered galena. Dixon Mine, Bingham Cañon, Salt Lake County, Utah. (14701.)
- (37) Anglesite, massive, showing the outlines of the original galena from which it was derived by direct oxidation; shows carbonates of copper on the outside. Raymond & Ely Mine, Ely district, Lincoln County, Nevada. (15307.)
- (38) Galena and tetrahedrite, in quartz, showing decomposition products, especially carbonates of copper. Esmeralda Mine, Esmeralda, Nye County, Nevada. (15266.)
- (39) Galena, blende, and tetrahedrite, in quartz, much decomposed, showing especially the carbonates of copper. Emily Mine, Little Cottonwood district, Salt Lake County, Utah. (14674.)
- (40) Cerussite, crystallized on limonite. Iron Mine, Leadville, Lake County, Colorado. (5438.)
- (41) Cerussite, crystallized, very pure; surface specimen. Bingham Cañon, Salt Lake County, Utah. (55376.)
- (42) Cerussite, crystallized in small crystals on massive cerussite. Morning Star Mine, Leadville, Lake County, Colorado. (32491.)
- (43) Cerussite, a few crystals on massive cerussite. Morning Star Mine, Leadville, Lake County, Colorado. (65375.)
- (44) Cerussite, wholly massive. Morning Star Mine, Leadville, Lake County, Colorado. (65376.)
- (45) Cerussite, massive. Conly Mine, Eureka, district, Eureka County, Nevada. (15483.)
- (46) Cerussite, crystalline and somewhat impure. Vanderbilt Mine, Bingham district, Salt Lake County, Utah. (14750.)
- (47) Cerussite, crystalline and somewhat impure. Richmond Mine, Eureka district, Eureka County, Nevada. (15530.)
- (48) Cerussite, crystalline and somewhat impure. J. J. Corrigan Mine, Eureka district, Eureka County, Nevada. (15531.)
- (49) Cerussite, massive, impure. Evening Star Mine, Leadville, Lake County, Colorado. (32457.)
- (50) Cerussite, crystalline, impure. Containing 50 per cent. lead and 75 ounces silver. Niantic Mine, Lucien district, Box Elder County, Utah. (17071.)

- (51) Cerussite, massive, impure. Eureka Consolidated Mine, Eureka district, Eureka County, Nevada. (15523.)
- (52) Cerussite, massive, impure. Eureka Consolidated Mine, Eureka district, Eureka County, Nevada. (65371.)
- (53) Cerussite, massive, impure. Chaney Mine, Bradshaw district, Beaver County, Utah. (14651.)
- (54) Cerussite, massive, impure. Emma Mine, Little Cottonwood district, Salt Lake County, Utah. (18045.)
- (55) Cerussite, impure, in powder. Commonly called sand carbonate. Rebellion Mine, Pinyon Hill, Summit County, Utah. (55350.)
- (56) Cerussite, impure, in powder. Very rich, 1,490 ounces silver per ton. Commonly called sand carbonate. Matchless Mine, Leadville, Lake County, Colorado. (56435.)
- (57) Cerussite, impure, in powder. Very rich, 2,704 ounces silver per ton. Commonly called sand carbonate. Robert E. Lee Mine, Leadville, Lake County, Colorado. (56437.)
- (58) Cerussite, crystalline powder, containing also crystals of wulfenite. Commonly called sand carbonate. Eureka district, Eureka County, Nevada. (30566.)

THE SMELTING OF BASE BULLION.

In carrying on the smelting of base bullion it is necessary to have a sufficient supply of ores carrying a suitable percentage of lead, if ores carrying high percentages are available, then ores with only a small percentage, or none at all, may be mixed with them. Ores low in lead are known as dry ores. The smelting operation is generally carried on in a shaft furnace, the use of the reverberatory furnaces being mainly confined to ores carrying, in addition to the lead and silver, a considerable percentage of copper. Ores that exist in the oxidized state and those containing only a small percentage of sulphur are smelted directly, but if the ore is mainly a sulphide it must be subjected to a previous roasting operation to remove the greater portion of the sulphur. This roasting also removes some arsenic and antimony.

The most suitable ores for the operation are those containing only lead and silver minerals with quartz. It is seldom, however, that a large supply of such ores can be obtained, various other metals which influence more or less the smelting operation, the most objectionable of which is zinc, being frequently found in the ore. Various other gangues besides quartz are common, the most important being oxides of iron, calcite, and barite. The first two of these can be mixed with great advantage with quartzose ores, since the iron and lime will neutralize the silica, but the latter is quite objectionable.

The process of roasting the sulphide ores is carried out in two ways, depending on the character of the ore and its physical condition. If the ore is in lumps it is roasted in brick stalls, only sufficient fuel being used to start a vigorous combustion of the sulphur, the operation being completed by the heat furnished from the burning of the sulphur. If, however, the ore is in the form of a powder, it is roasted in reverberatory furnaces, which are heated by flame, either from wood, soft coal, or gas. The ore is introduced at the coldest end of the furnace and is gradually

worked along, as the roasting proceeds, to the end nearest to the fire, where the heat is generally sufficient to fuse the roasted ore.

Having a good supply of oxidized ores of a suitable character, and roasted sulphide ores, they are subjected to fusion in a shaft furnace for the extraction of the lead and silver in the form of an alloy. Great care is necessary in mixing the different ores and fluxes in order to produce a proper charge for the furnace. The objects of the fusion are to remove the silver and lead from the ore in the form of metal, and to separate the earthy material in the form of a slag, sufficiently free from the metals to be rejected.

The ores and fluxes are mixed in such a manner that a suitable silicate slag shall be formed by the silica and the basic constituents of the mixture. This slag must be readily fusible at the temperature of smelting, so as to flow freely from the furnace, and it must be fluid enough to allow the bullion to settle through it to the bottom of the furnace. It must not contain too much of either lead or silver, as, when such is the case, it has to be returned to the furnace and be resmelted.

The gangue of the ore being mainly quartzose or acid, the fluxes must be basic and are for the most part limestone and oxides of iron and manganese. In some localities these latter are frequently found carrying a small amount of silver, which will be extracted during the operation.

Having determined upon a certain mixture for smelting the various materials must be suitably mixed before being charged into the furnace. This is generally accomplished by making up beds of alternate layers of the different materials and then taking off vertical sections of these beds and charging them into the furnace with a suitable amount of fuel.

The furnaces in which the fusion takes place vary greatly in the details of their construction, but they consist essentially of a stack with a flue at the top, connecting with a suitable draft stack, through dust chambers, and closed at the bottom. At a suitable distance from the top is a door for the introduction of the charge, and at the bottom are openings for the introduction of air, and for the withdrawal of the bullion and slag; in most cases the metal and slag are drawn off separately, but in some cases they are drawn off together. Besides the waste slag and the valuable bullion, two intermediate by-products are frequently formed. The first of these is called matte and consists of sulphides, mainly of iron, formed from the sulphur remaining in the ore as charged, and generally containing a valuable amount of silver. When the ore mixture contains copper it is found mostly in the matte and may occur in sufficient amount to be valuable. Where small amounts of matte are produced it is either thrown away or allowed to accumulate until a considerable amount is on hand, when, as also where large amounts are produced, it is roasted and forms a valuable flux, on account of the oxide of iron it then contains. The second by-product is called speiss, and it is found in smelting ores containing arsenic. It is essentially an arsenide of iron.

Large amounts of base bullion are smelted at works located in and near the mining regions, and the base bullion is shipped to other works for refining or to separate the silver from the lead.

COLORADO SMELTER.

To illustrate the smelting of base bullion a very complete collection from the works of the Colorado Smelting Company, South Pueblo, Colorado, is shown. The diagram, figure 3, illustrates the process followed at these works.

The ores as received at the works are classified into oxidized and sulphureted; the oxidized ores are further divided into basic and siliceous, that is, basic ores, the gangue of which is essentially a base, and siliceous ores, the gangue of which is essentially acid or silica. These are sent directly to the shaft furnaces. The sulphureted ores are also divided into basic and siliceous; in this case, however, it is the ores that are high in sulphur that are called basic, for the reason that on roasting they furnish mainly oxides, which act as bases in the smelting operation. The siliceous sulphureted ores consist essentially of quartz, with only a small amount of sulphides. They are generally very rich in silver and poor in lead, being more nearly true silver ores.

The basic sulphureted ores are separated into coarse and fine. The coarse are roasted in stalls and then go to the shaft furnaces; the fine are roasted in reverberatory furnaces and are sometimes fused at the end of the roasting and sometimes are not. From the roasting furnaces they go direct to the shaft furnaces. The siliceous sulphureted ores are sometimes roasted in the fusion furnace, but they are generally sent to the shaft furnace, especially when they are very rich in silver.

The fluxes are all basic and consist of iron ores and limestone and go direct to the shaft furnaces.

The products of the smelting in the blast furnaces are:

(1) Base bullion which goes to the market. The bullion from these furnaces holds a high position with the refineries on account of its freedom from impurities, due to the purity of the ores from the Madonna mine, which form a large proportion of the charge in the shaft furnaces. It varies in richness, although it generally carries 300 ounces of silver per ton and about an ounce of gold. It is cast into bars or pigs weighing 98 pounds and is shipped from the furnace in car loads of 300 bars.

(2) Slag, which is divided into clean, or free from lead and silver, which is thrown over the dump, and impure, that is, containing lead and silver, which goes back to the shaft furnace.

(3) Matte, which goes to the roasting stalls and then back to the shaft furnaces.

(4) Speiss, which goes to the roasting stalls and then back to the shaft furnaces.

(5) Flue dust, which is mixed with lime and ores low in lead, roasted in the fusion furnace, and then goes back to the shaft furnaces.

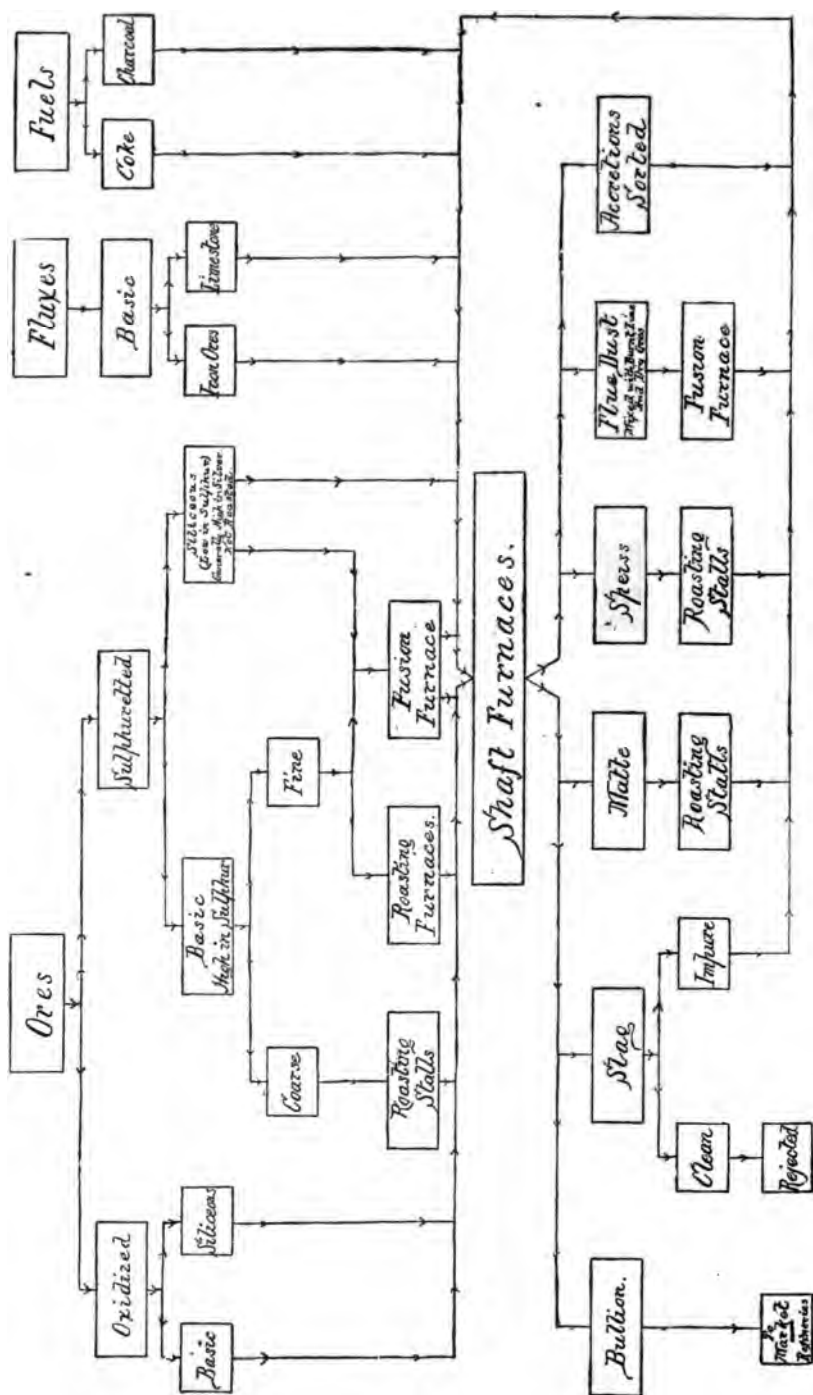


FIG. 3
Scheme showing the operations of the Colorado smelter.

(6) Accretions, which are deposits formed upon the walls of the furnace. These are assorted according to their characteristics and then go to the shaft furnaces.

A general view of the works is shown on PL. VI. The yard and stalls for roasting the coarse sulphide ores are shown on PL. VII. The interior of the shaft-furnace house at the tap-hole level is shown on PL. VIII.

The collection shows a large variety of the ores, together with roasted ores, the fluxes, the base bullion, the slag, the by-products of both, the roasting and smelting operations, and the final products. It was prepared by Mr. Anton Eilers, the manager of the company in 1885-'86.

Ores.

The basic oxidized ores treated at these works are almost entirely obtained from the Madonna mine, Monarch, Chaffee County, Colorado. The ores consist for the most part of carbonate of lead (cerussite), much of it being in the form of sand, colored by iron. Occasionally unaltered galena is found, and occasionally, also, the sulphate (anglesite) is found. The following eighteen specimens show the different varieties of ores from this mine:

(1) Sand carbonate, consisting of a mixture of carbonate and sulphate of lead and oxide of iron. This specimen represents the bulk of the ore body of the mine, (51074.) the typical analysis* of which is as follows:

	Per cent.	Remarks.
Sequoioxide of iron (Fe_2O_3)	32.99	(Fe varies from 13.0 to 33.5).
Sequoioxide of manganese (Mn_2O_3)	0.93	
Alumina (Al_2O_3)	2.99	
Oxide of zinc (ZnO)	4.17	(As silicate).
Lime (CaO)	1.78	(CaCO_3 —3.18).
Magnesia (MgO)	None.	
Sulphate of lead (PbSO_4)	12.47	(Pb varies from 20.0 to 45.0).
Carbonate of lead (PbCO_3)	32.35	
Arsenic (As)	Faint trace.	
Antimony (Sb)	Faint trace.	
Copper (Cu)	None.	
Silica (SiO_2)	4.24	
Sulphuric anhydride (SO_3)	3.30	(S—1.32.)
Carbonic acid (CO_2)	6.73	
Water (H_2O)	6.68	
Sulphur (S)	Trace.	(In sulphides.)
Silver (Ag)	0.023	Or 6.8 ounces per ton (varies from 5 to 12 ounces per ton).

(2) Cerussite, crypto-crystalline in structure and very pure, assaying 74 per cent. of lead and 14 ounces of silver per ton. (51055.)

(3) Cerussite, dark, showing a few crystals. This variety of ore averages by assay 66.5 per cent. of lead and 5.1 ounces of silver per ton. (51059.)

*All the analyses and assays in this collection were made by Mr. Robert Sticht, the chief chemist of the company, except as otherwise noted.

(4) Cerussite, massive, granular, colored with a little iron. This variety of ore averages by assay 60.7 per cent. of lead and 8 ounces of silver per ton. (51063.)

(5) Cerussite, massive, compact. (51061.)

(6) Cerussite, massive and crystalline, with streaks of oxide of iron. (51060.)

(7) Cerussite, massive, granular, in gray and black streaks. (51070.)

(8) Cerussite, crystalline, in layers, a little stained with iron. (51071.)

(9) Cerussite and anglesite, stained with iron. (51065.)

(10) Cerussite and anglesite, exhibiting the cubical structure of the original galena. (51066.)

(11) Anglesite, showing decomposition to cerussite. (51064.)

(12) Anglesite, very pure, exhibiting in great beauty and perfection the cubical structure of the original galena, quite a common character of the lump ore. The average of this ore by assay is 57.5 per cent. lead and 31.1 ounces of silver. A specimen picked for its purity showed sulphate of lead 99.65 per cent., sesquioxide of iron 0.075 per cent., and silica, arsenic, antimony, copper, zinc, and manganese not present, while the silver varied from 2 to 30 ounces per ton. (51056.)

(13) Anglesite, inclosing cerussite, a rare occurrence. (51068.)

(14) Galena, fine grained, fibrous, coated with cerussite, stained with iron; shows also a little iron pyrite and native sulphur. This character of ore averages by assay 76.2 per cent. lead, and 12.2 ounces of silver per ton. (51058.)

(15) Galena, showing decomposition to anglesite and then to cerussite, stained on the outside with iron. (51062.)

(16) Galena, fine grained and slightly fibrous, showing decomposition to sulphate. This variety of ore averages by assay 67.5 per cent. lead and 27 ounces of silver per ton. (51057.)

(17) Galena, shows coarse cleavage and is coated by decomposition products. Assays silver 23 ounces per ton. (51067.)

(18) Native sulphur, a rare occurrence of the decomposition of galena. (51069.)

A single illustration of oxidized siliceous ore is shown:

(1) Chert, stained with iron. Small Hopes Mine, Leadville, Lake County, Colorado. (51052.) This ore is of the following composition:

Iron (Fe) varies from	25 to 38 per cent.
Silica (Si O ₂) varies from	27 to 57 per cent.
Lead (Pb) varies from	0 to 0 per cent.
Silver (Ag) varies from	80 to 210 ounces per ton.

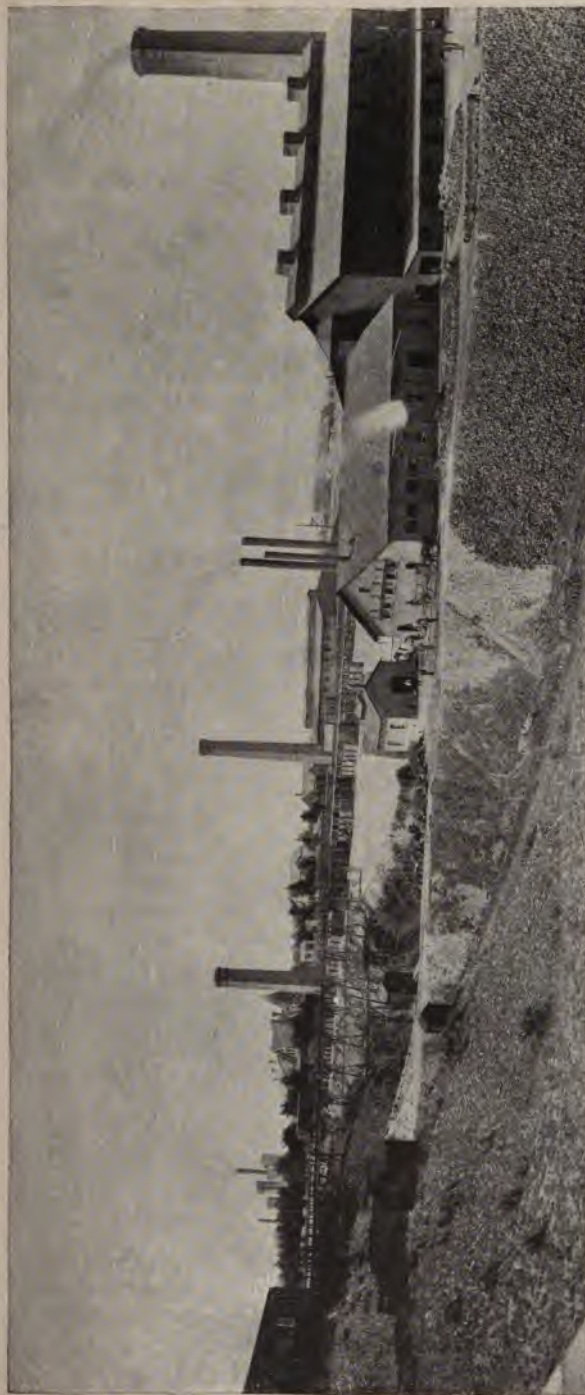
The basic sulphide ores are represented by three specimens:

(1) Galena, blende, and pyrite, in lumps for roasting in stalls. Colonel Sellers Mine, Leadville, Lake County, Colorado. (51072.) The average composition of this ore is as follows:

Lead (Pb).....	30.53 per cent. (varies from 20 to 40 per cent.)
Zinc (Zn)	16.33 per cent. (varies from 12 to 29 per cent.)
Iron (Fe).....	14.42 per cent.
Silica (SiO ₂).....	5.96 per cent.
Sulphur (S).....	29.24 per cent.
Silver (Ag).....	40 ounces per ton (varies from 20 to 60 ounces per ton).

(2) Galena and blende, with a little chalcopyrite and quartz, in lumps for roasting in stalls. Cusiuhiriachic Mining Company, Chihuahua, Mexico. (51073.) A typical analysis of this ore is as follows:

Lead (Pb).....	45.00 per cent. (varies from 8 to 53 per cent.)
Zinc (Zn)	11.88 per cent. (varies from 6 to 16 per cent.)
Iron (Fe).....	3.88 per cent.
Silica (SiO ₂).....	20.00 per cent.
Silver (Ag).....	110 ounces per ton (varies from 100 to 200 ounces per ton).
Gold (Au).....	0.05 ounce per ton (varies from 0.05 to 0.35 ounce per ton).



GENERAL VIEW OF THE "COLORADO SMELTER," SOUTH PUEBLO, COLORADO.
(See explanation, page XIII.)

(3) Galena, blende, pyrite, with a little quartz; fine ore, for roasting in reverberatory furnace. Colonel Sellers Mine, Leadville, Lake County, Colorado. (51075.) Composition the same as No. 51072.

To illustrate the siliceous sulphureted ores two specimens are shown:

(1) Quartz, containing small amounts of sulphides and stained by decomposition products, especially carbonates of copper. Eureka Hill Mine, Tintic District, Tooele County, Utah. (51051.) The composition is as follows:

Iron (Fe) varies from	3.0 to 5.0 per cent.
Silica (SiO_2) varies from	50.0 to 80.0 per cent.
Sulphur (S) varies from	0.08 to 2.2 per cent.
Lead (Pb) varies from	5.0 to 8.0 per cent.
Silver (Ag) varies from	30.0 to 60.0 ounces per ton.
Gold (Au) varies from	0.05 to 0.08 ounce per ton.

(2) Quartz and calcite, containing small amounts of sulphides; crushed ore. Guanajuato, Mexico. (51077.)

The composition of this ore is as follows:

	Per cent.
Silica (SiO_2)	71.87
Iron (Fe)	2.29
Manganese (Mn)	trace
Alumina (Al_2O_3)	3.33
Lime (CaO)	5.78
Magnesia (MgO)	1.58
Sulphate of barium (BaSO_4)	trace
Zinc (Zn)	trace
Arsenic (As)	trace
Copper (Cu)	trace
Antimony (Sb)	0.75
Lead (Pb)	0.14
Sulphur (S)	1.46
Carbonic acid (CO_2)	6.27
Silver (Ag) 855.75 ounces per ton	2.934

Fluxes.

To illustrate the iron ore fluxes two samples are shown:

(1) Consisting essentially of the hydrated sesquioxide of iron (limonite). It is found in connection with the lead ores in the mine, and is probably the result of decomposition of the original pyrite in the upper portions of the vein. Besides lead, it also contains a small amount of silver. Madonna Mine, Monarch, Chaffee County, Colorado. (51053.) A typical analysis of this ore is as follows:

Iron (Fe)	42.05 per cent.
Manganese (Mn)	3.12 per cent.
Silica (SiO_2)	5.10 per cent.
Zinc (Zn)	1.86 per cent.
Sulphur (S)	0.02 per cent.
Lead (Pb)	4.0 to 9.0 per cent.
Silver (Ag)	2.0 to 5.0 ounces per ton.

(2) Consisting essentially of the hydrated sesquioxide of iron (limonite), but containing a considerable amount of manganese. It is found in connection with the lead ore in the mine and is probably the result of the decomposition of the original pyrite in the upper portions of the vein. It contains little or no lead, but a valuable amount of

silver. Fryer Hill, Leadville, Lake County, Colorado. (51054.) A typical analysis of this is as follows:

Iron (Fe)	36.44 per cent.
Manganese (Mn)	16.99 per cent.
Silica (SiO ₂)	8.76 per cent.
Lead (Pb)	none, by assay.
Silver (Ag)	8.0 to 10.0 ounces per ton.

A single illustration of limestone, used for flux, from Pueblo, Colorado, is shown. (51046.)

A typical analysis of the limestone is as follows:

	Per cent.
Lime (CaO)	52.34
Carbonic acid (CO ₂)	41.12
Sesquioxide of iron (Fe ₂ O ₃) and alumina (Al ₂ O ₃)	3.20
Silica (SiO ₂)	4.40

Three samples of roasted ores are shown, one to represent each character of roasting practiced.

(1) Roasted ore, the lump ore from the Colonel Sellers Mine, Leadville, Lake County, Colorado, represented by specimen No. 51072, after having been roasted in the roasting stalls. (51045.) A typical analysis is as follows:

	Per cent.
Oxide of lead (PbO)	27.98
Oxide of zinc (ZnO)	27.12
Sesquioxide of iron (Fe ₂ O ₃)	28.36
Protos Sesquioxide of manganese (Mn ₂ O ₄)	1.04
Alumina (Al ₂ O ₃)	trace
Lime (CaO)	1.7c
Silica (SiO ₂)	4.63
Sulphur (S) mostly present as sulphuric anhydride (SO ₃)	5.28
Silver (Ag) 45.4 ounces per ton	0.156

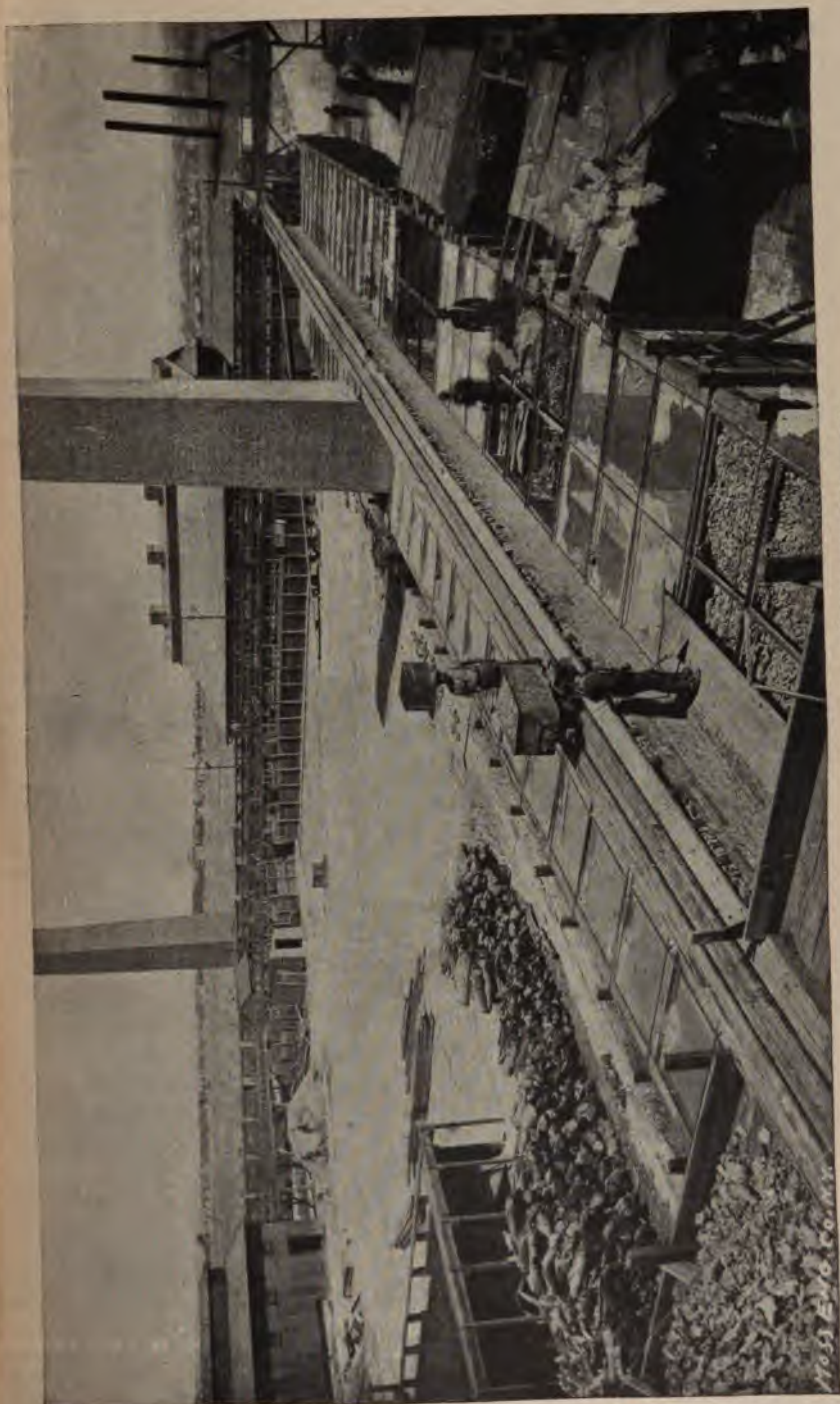
(2) Roasted ore, the concentrated ore from the Colonel Sellers Mine, Leadville, Lake County, Colorado, represented by specimen, No. 51075, after having been roasted in the reverberatory furnace. (51076.) A typical analysis is as follows:

	Per cent.
Oxide of lead (PbO)	27.06
Oxide of zinc (ZnO)	30.82
Sesquioxide of iron (Fe ₂ O ₃)	32.69
Protos Sesquioxide of manganese (Mn ₂ O ₄)	0.23
Lime (CaO)	1.36
Magnesia (MgO)	none
Alumina (Al ₂ O ₃)	2.31
Oxide of copper (CuO)	0.68
Silica (SiO ₂)	4.64
Sulphuric anhydride (SO ₃)	4.05
Sulphur (S)	1.00
Silver (Ag) 42.5 ounces per ton	0.146

} total S. 2.62

(3) Fused ore, the result of roasting the flue dust from the shaft furnaces, mixed with siliceous sulphureted ores, in the fusion furnace. Locally known as gray slag. (51050.) The analysis is as follows:

	Per cent.
Oxide of lead (PbO)	20.21
Sesquioxide of iron (Fe ₂ O ₃)	30.88
Sesquioxide of manganese (Mn ₂ O ₃)	1.64
Alumina (Al ₂ O ₃)	1.28



YARD AND ROASTING STALLS OF THE "COLORADO SMELTER."
(See explanation, page XIII.)

	Per cent.
Oxide of zinc (ZnO)	5.04
Lime (CaO)	12.33
Silica (SiO ₂)	28.75
Arsenic (As)	not present
Copper (Cu)	not present
Antimony (Sb)	trace
Sulphur (S)	trace only
Silver (Ag) 3 ounces per ton	0.01

Fuel.

(1) Coke, El Moro, Las Animas County, Colorado. (51332.) .

	Per cent
Water (H ₂ O)	0.28
Fixed carbon, by difference	83.77
Ash	15.95
	100.00

Composition of ash:

Silica (SiO ₂)	10.66
Sesquioxide of iron (Fe ₂ O ₃)	1.03
Alumina (Al ₂ O ₃)	3.85
Lime (CaO)	0.15
Undetermined	0.26

(2) Piñon pine charcoal. (51333.)

Products.

(1) Base bullion or argentiferous lead. Contains the lead and silver of the materials charged into the furnaces, and also the small amount of gold. The amount of gold and silver varies, though the silver has never exceeded 350 ounces per ton and the gold 1.5 ounces per ton. Owing to the exceptional purity of the Madonna ores, which enter largely into the shaft furnace charge, the bullion is very free from impurities and is very easy to refine. It is shipped from the works in car loads of 300 bars, weighing 98 pounds each. (51080.)

(2) Base bullion. Cores of metal taken from the bar, one from the top and one from the bottom of each, in order to determine its value by assay. (51089.)

(3) Base bullion, assay sample; consisting of the cores represented by No. 51089, taken from each bar of the shipment. These cores are melted down and cast into a bar, and samples are cut from each end and the middle, which are assayed to determine the value of the shipment. (51081.)

The slags resulting from the smelting operation, change frequently with changes in the ore charge, but the limit of the changes within which the furnaces will work clean and successfully is quite small, when, however, the furnace is not working properly abnormal slags of very varying composition are formed. The principal constituents of clean slags are silica, protoxide of iron and lime, and to these in certain cases may be added oxide of zinc. The varying proportions of these elements constitute the difference in the slags. The following are examples of clean slags:

(1) (51082): Showing square prismatic crystals of the following composition:

	Per cent.
Silica (SiO ₂)	30.665
Protoxide of iron (FeO) *	23.70
Protoxide of manganese (MnO)	1.51

* Iron (Fe) 18.56.

	Per cent.
Alumina (Al_2O_3)	4.74
Oxide of zinc (ZnO)	13.75
Lime (CaO)	23.005
Oxide of lead (PbO)	1.556
Sulphur (S)	1.12

(2) (51083): Showing bladed crystals of the following composition:

	Per cent.
Silica (SiO_2)	34.51
Protoxide of iron (FeO)	32.08
Protoxide of manganese (MnO)	4.56
Alumina (Al_2O_3)	not determined
Lime (CaO)	16.28
Oxide of zinc (ZnO)	6.97
Sulphur (S)	3.06
Oxide of lead (PbO)	1.74

(3) (51084): Showing confused bladed crystals of the following composition:

	Per cent.
Silica (SiO_2)	35.65
Protoxide of iron (FeO) †	31.68
Protoxide of manganese (MnO)	2.07
Alumina (Al_2O_3)	3.55
Oxide of zinc (ZnO)	7.55
Lime (CaO)	17.91
Oxide of lead (PbO)	1.47
Sulphur (S)	1.60

(4) (51085): Showing thick rhombohedral crystals of the following composition:

	Per cent.
Silica (SiO_2)	36.00
Protoxide of iron (FeO) †	23.66
Protoxide of manganese (MnO)	1.05
Alumina (Al_2O_3)	not determined
Lime (CaO)	25.70
Oxide of zinc (ZnO)	9.00
Oxide of lead (PbO)	1.71
Sulphur (S)	1.33

(5) (51086): Showing crystals in sheaves of the following composition:

	Per cent.
Silica (SiO_2)	35.62
Protoxide of iron (FeO) §	20.20
Protoxide of manganese (MnO)	8.91
Alumina (Al_2O_3)	3.83
Oxide of zinc (ZnO)	5.57
Lime (CaO)	17.90
Oxide of lead (PbO)	1.53
Sulphur (S)	1.61

(6) Short, thick, prismatic crystals. (51088.)

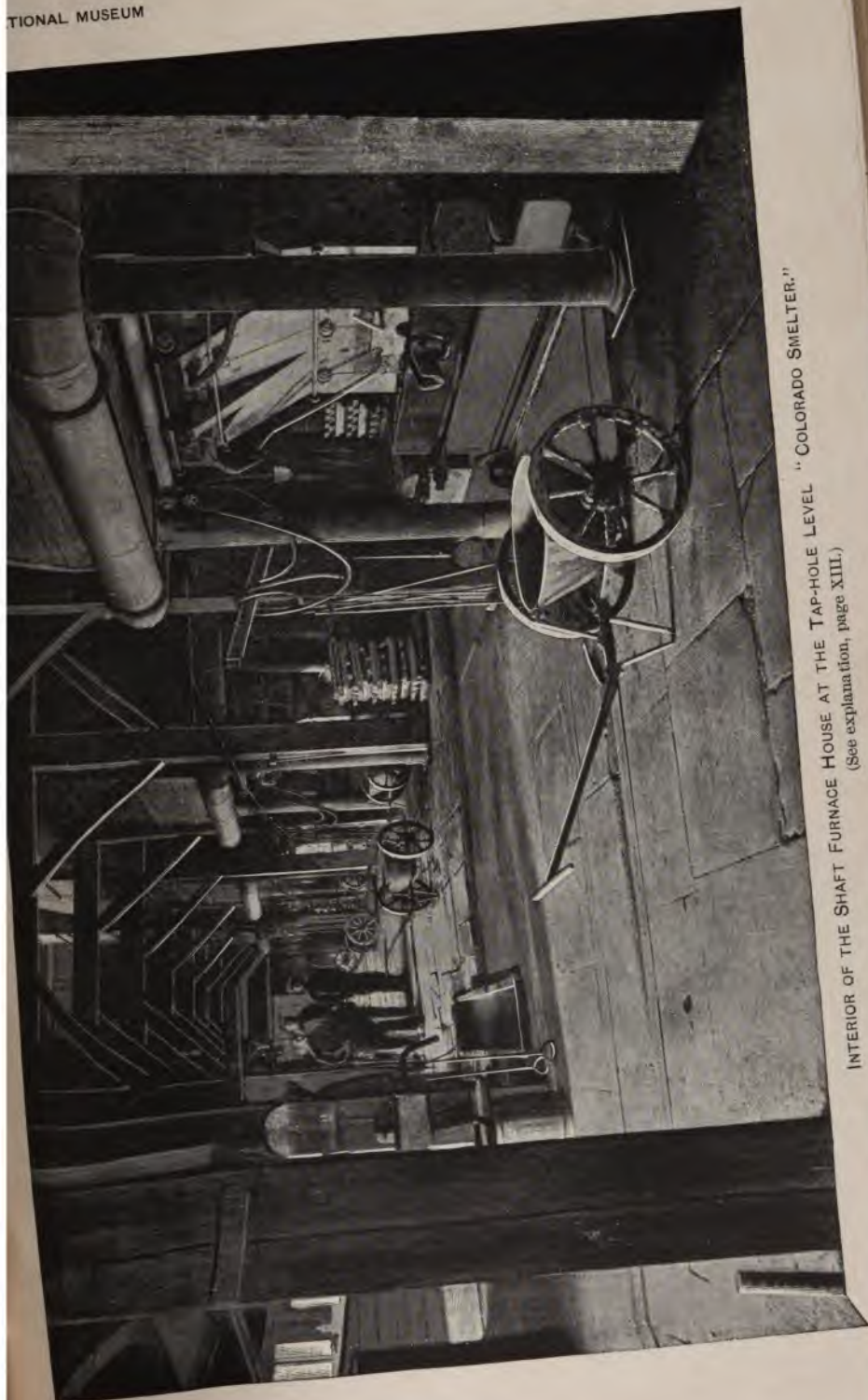
The following five specimens, the analyses of which were made by Mr. A. S. Dwight, M. E., represent the impure slags or those which

* Iron (Fe) 24.95.

† Iron (Fe) 24.64 per cent.

‡ Iron (Fe) 18.41.

§ Iron (Fe) 20.38 per cent.



INTERIOR OF THE SHAFT FURNACE HOUSE AT THE TAP-HOLE LEVEL "COLORADO SMELTER."
(See explanation, page XIII.)

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contain a valuable amount of metals. They are recharged into the blast furnace:

Stoney (51327.)

	Per cent.
Silica (SiO_2)	33.27
Protoxide of iron (FeO)	37.76
Protoxide of manganese (MnO)	1.42
Alumina (Al_2O_3)	4.46
Oxide of zinc (ZnO)	4.02
Lime (CaO)	14.24
Magnesia (MgO)	trace
Oxide of lead (PbO)	1.46
Sulphur (S)	2.04

Crystallized (51328.)

	Per cent.
Silica (SiO_2)	31.16
Protoxide of iron (FeO)	31.34
Protoxide of manganese (MnO)	1.37
Alumina (Al_2O_3)	4.15
Oxide of zinc (ZnO)	9.01
Lime (CaO)	18.66
Magnesia (MgO)	trace
Oxide of lead (PbO)	1.83
Sulphur (S)	1.39

Crystallized (51329.)

	Per cent.
Silica (SiO_2)	32.13
Protoxide of iron (FeO)	32.03
Protoxide of manganese (MnO)	1.27
Alumina (Al_2O_3)	4.13
Oxide of zinc (ZnO)	9.23
Lime (CaO)	18.86
Magnesia (MgO)	trace
Oxide of lead (PbO)	2.35
Copper (Cu)	trace
Sulphur (S)	1.43

Stoney (51330.)

	Per cent.
Silica (SiO_2)	30.34
Protoxide of iron (FeO)	32.13
Protoxide of manganese (MnO)	1.32
Alumina (Al_2O_3)	3.80
Oxide of zinc (ZnO)	6.44
Lime (CaO)	22.72
Oxide of lead (PbO)	1.40
Sulphur (S)	1.39

Stoney (51,331.)

	Per cent.
Silica (SiO_2)	31.79
Protoxide of iron (FeO)	31.77
Protoxide of manganese (MnO)	3.05
Alumina (Al_2O_3)	6.50
Oxide of zinc (ZnO)	6.72
Lime (CaO)	15.58

	Per cent.
Magnesia (MgO).....	trace
Oxide of lead (PbO).....	2.53
Copper (Cu).....	trace
Sulphur (S).....	2.57

By products.

Five samples of the intermediate products, matte and speiss, are shown.

(1) Matte, which is formed during the smelting operation and settles to the bottom of the slag pot when drawing off slag. Consisting of various sulphides, especially iron. (51048.) A typical analysis is as follows:

	Per cent.
Iron (Fe)	52.27 (varies from 48.00 to 56.00)
Lead (Pb).....	10.72 (varies from 4.5 to 15.00)
Zinc (Zn).....	4.27
Sulphur (S)	24.015
Copper (Cu).....	0.61
Arsenic (As).....	0.56
Antimony (Sb)	none
Lime (CaO).....	0.41 (presence accidental)
Magnesia (MgO).....	0.47 (presence accidental)
Oxygen (O)	not determined.
Silver (Ag).....	0.084 or 24.5 ounces per ton (varies from 21 to 45 ounces per ton).

(2) Matte, after roasting in stalls, whereby the sulphides are changed for the most part into oxides. It is a valuable flux on account of the oxide of iron which it contains. (51044.) A typical analysis is as follows:

	Per cent.
Sesquioxide of iron (Fe_2O_3)	80.39 (Iron (Fe), 56.27)
Sesquioxide of manganese (Mn_2O_3).....	0.93
Oxide of lead (PbO).....	7.91 (Lead (Pb), 7.34)
Oxide of zinc (ZnO).....	0.98
Oxide of copper (CuO)	3.22
Arsenous acid (As_2O_3).....	0.86 (Arsenic (As), 0.648)
Antimony (Sb)	trace
Sulphur (S)	1.01
Silica (SiO_2).....	3.21
Lime (CaO)	3.22 (presence accidental)
Silver (Ag).....	0.0614 or 17.9 ounces per ton.

(3) Speiss, an occasional product formed when smelting ores containing arsenic; it settles to the bottom of the slag pot below the matte, being much heavier. It is essentially an arsenide of iron, and is roasted in the stalls and then returned to the blast furnace. (51049.) Composition:

	Per cent.
Iron (Fe)	58.32
Arsenic (As)	30.005
Copper (Cu)	2.09
Sulphur (S).....	4.105
Lead (Pb)	1.87
Manganese (Mn)	not present.

	Per cent.
Zinc (Zn).....	not present
Antimony (Sb).....	trace
Nickel (Ni).....	trace
Cobalt (Co).....	trace
Insoluble residue.....	0.15
Silver (Ag).....	0.015 or 4.8 ounces per ton.

(4) Speiss, an occasional product formed when smelting ores containing arsenic; it settles to the bottom of the slag pot below the matte, being much heavier. It is essentially an arsenide of iron, and is roasted in the stalls and then returned to the blast furnace. (50927.) Composition:

	Per cent.
Iron (Fe).....	59.42
Arsenic (As).....	31.17
Copper (Cu).....	5.06
Lead (Pb).....	0.67
Sulphur (S).....	2.80
Nickel (Ni).....	trace
Cobalt (Co).....	trace
Antimony (Sb).....	trace
Silver (Ag).....	0.014 or 4.2 ounces per ton.
Insoluble residue.....	trace

(5) Matte and speiss, a compound piece, showing the separation of the two in the slag pot. (51047.)

The fine material that is carried forward by the blast is illustrated by a single sample:

(1) Flue dust, consisting of fine particles of the charge carried off by the blast and collected in the dust chambers attached to the shaft furnaces. It is mixed with quicklime and siliceous sulphureted ores and treated in the fusion furnace, after which it goes to the shaft furnaces. (51078.) The following is a typical analysis:

	Per cent.	
Oxide of lead (PbO).....	37.65	
Oxide of zinc (ZnO).....	5.32	
Sesquioxide of iron (Fe ₂ O ₃).....	24.98	
Sesquioxide of manganese (Mn ₂ O ₃).....	1.51	
Alumina (Al ₂ O ₃).....	1.31	
Lime (CaO).....	5.26	
Magnesia (MgO).....	none	
Copper (Cu).....	trace	
Silica (SiO ₂).....	8.63	
Sulphuric anhydride (SO ₃).....	1.61	} Total sulphur, 3.18.
Sulphur (S).....	2.53	
Carbonic acid (CO ₂).....	} 11.20 (loss on ignition).	
Water (H ₂ O).....		
Carbonaceous matter.....		
Silver (Ag).....	0.04 or 11.7 ounces per ton	

To represent the wall accretions which gather on the sides of the furnaces, and which are first sorted and then returned to the shaft furnaces, four specimens are shown.

(1) Red oxide of lead (minium), formed in the mortar joints in the crucible of the shaft furnaces. (51041.)

(2) Furnace accretion, formed on the walls of the shaft furnace when smelting ores

containing zinc. (51043.) It consists essentially of sulphide of zinc of the following composition :

	Per cent.
Zinc (Zn).....	45.68
Lead (Pb).....	1.48
Iron (Fe).....	6.71
Manganese (Mn).....	0.54
Sulphur (S).....	25.98
Antimony (Sb).....	trace
Arsenic (As).....	not present
Copper (Cu).....	not present
Silica (SiO ₂).....	8.13
Lime (CaO).....	6.20
Silver (Ag).....	0.0188 or 5.5 ounces per ton

(3) Finely crystallized, nearly pure, sulphide of zinc. (50926.)

(4) Furnace accretion, formed on the walls of the shaft furnace when smelting ores containing zinc. (51042.) This sample contains considerable lead and is of the following composition :

	Per cent.
Zinc (Zn).....	38.99
Lead (Pb).....	37.48
Iron (Fe).....	0.94
Lime (CaO).....	0.30
Sulphur (S).....	19.74
Silica (SiO ₂).....	0.57
Arsenic (As).....	not present
Copper (Cu).....	not present
Manganese (Mn).....	not present
Antimony (Sb).....	0.12
Silver (Ag).....	variable, from 15 to 36 ounces per ton throughout piece

When roasting the speiss in stals previous to returning it to the shaft furnaces very beautiful and interesting sublimation products are formed, consisting of the sulphides and oxide of arsenic. These are illustrated by three specimens :

- (1) Yellow sulphide of arsenic (orpiment). (51040.)
- (2) Arsenious acid in octahedral crystals of great beauty. (51079.)
- (3) Oxide and sulphides of arsenic (arsenious acid, orpiment, and realgar). Four specimens. (51038.)

REFINING BASE BULLION.

The base bullion resulting from the first smelting operation is charged into large reverberatory furnaces and melted. In some cases only a single brand of pig lead is melted in the charge, but generally several brands are mixed, rich with poor, and very impure with quite pure, the object being to get a mixture containing the right proportion of silver and also to assist the removal of impurities from the very impure material.

Upon becoming melted any residue of unmelted dross is drawn off from the melted lead and the bath is submitted to an oxidizing action to remove the impurities; as fast as these accumulate upon the surface they are withdrawn. As soon as the bath is purified or softened suffi-

ciently it is drawn off into large kettles, where it is kept melted, and metallic zinc in several portions is successively added. This zinc forms an alloy with the silver and rises to the top of the melted lead, when it is skimmed off. These zinc scums containing the silver are gently heated for a considerable time (liquated) to remove excess of lead; the liquated scums are then subjected to distillation to remove the zinc. The resulting alloy of silver and lead is then melted in a cupel and submitted to oxidation, whereby the lead is removed in the form of litharge, and the silver remains behind as metal, which is cast into ingots and sold.

The lead from which the silver has been removed by zinc retains a small amount of zinc, and this is removed by oxidation in a furnace similar to the softening furnace. From this furnace it is drawn off into a kettle and poled with green wood to purify it. The market or soft lead of commerce from the kettle is cast into pigs and sold.

THE CHELTENHAM SMELTING AND REFINING WORKS.

These works are located just outside of St. Louis, Missouri, and draw their supply of ores from the whole western mining region. The collection shown is confined to the refining operation and is selected from a complete collection of the works taken by Mr. J. P. Gazzam, E. M., September, 1884.

- (1) Base bullion, from blast-furnaces melting. (57386.)
- (2) First skimmings from softening furnace. (57387.)
- (3) Second skimmings from softening furnace. (57388.)
- (4) Softened base bullion. (57389.)
- (5) Spelter (metallic zinc), used to desilverize the lead. (57390.)
- (6) Zinc scums, containing the silver of the base bullion, from the desilverizing kettles. (57391.)
- (7) Desilverized lead, containing zinc. (57392.)
- (8) Skimmings from the refining furnace, containing zinc. (57393.)
- (9) Polings from refining kettle. (57394.)
- (10) Market lead. (57395.)
- (11) Zinc, distilled from scums. (57398.)
- (12) Rich silver-lead alloy, remaining in the retorts after distilling the zinc; contains gold. Doré alloy. (57397.)
- (13) Rich silver-lead alloy, remaining in the retorts after distilling the zinc. (57396.)
- (14) Litharge, from cupelling Doré alloy. (57400.)
- (15) Litharge, from cupelling silver-lead alloy. (57399.)
- (16) Fine silver. (57401.)
- (17) Coal, used for fuel. From Bryden, Illinois. (57404.)
- (18) Coke, from Bryden coal. (57405.)

KANSAS CITY SMELTING AND REFINING COMPANY.

To illustrate the smelting of base bullion and the refining of the bullion combined, a collection from the works of the Kansas City Smelting and Refining Company at Argentine, Kansas, is shown.

The process of smelting base bullion followed here is, in general, the same as at South Pueblo, Colorado, the principal difference being that

a much larger proportion of oxidized ores is treated and scrap iron is added to the charge in order to reduce the lead from the sulphide, so that the sulphide ores used are not roasted previous to smelting.

The blast-furnace charge is made up as follows :

	Pounds.
Ore, mixture of several, mainly sulphides	200
Ore, Viola, oxidized	100
Ore, litharge, (oxide of lead) from refining furnaces	45
Reducing agent, scrap wrought iron	10
Reducing agent and flux, iron scale, consisting of a mixture of metallic iron, with iron oxides	30
Flux, cinder from puddle furnace	30
Flux, limestone	40
Flux, rich slag from former smelting, 8 to 10 shovels.	
Fuel, coke from Connellsville, Pennsylvania	70

The base bullion resulting from this charge is slowly melted in 33-ton lots, skimmed and softened, and then run into the desilverizing kettles; in these two or three additions of zinc are made, according to circumstances, and the zinc scums and the desilverized lead are treated as described above.

The collection was taken by Mr. E. L. Zukoski, E. M., September, 1884, and shows a variety of the sulphide ores from Idaho (a large amount of which is received at the works in the form of concentrates), the oxidized ores from New Mexico, the fuel and fluxes, the base bullion, slags, etc., of the first smelting, and various steps in the refining process.

The sulphide ores are represented by the following specimens :

- (1) Concentrates, first-class ore, crushed coarse; consisting of galena with some blende. O. K. Mine, Alturas County, Idaho. (54991.)
- (2) Concentrates, second-class ore, crushed fine; containing a larger proportion of blende. O. K. Mine, Alturas County, Idaho. (54992.)
- (3) Concentrates, first-class ore; consisting almost entirely of galena, and containing 62.75 per cent. of lead and 71.97 ounces of silver per ton. Hailey Mine, Alturas County, Idaho. (54993.)
- (4) Concentrates, first-class ore, coarse lumps; consisting almost entirely of galena, but showing some tetrahedrite, and containing 66.87 per cent. of lead and 298.45 ounces of silver per ton. Parker Mine, Alturas County, Idaho. (54994.)
- (5) Concentrates, first-class ore, crushed coarse; consisting almost entirely of galena, but showing a little blende and pyrite, and containing 69.87 per cent. of lead and 66.8 ounces of silver per ton. Idahoian Mine, Alturas County, Idaho. (54995.)
- (6) Concentrates, first-class, in coarse lumps; consisting almost entirely of galena, but showing a little blende, and containing 69.12 per cent. of lead and 78 ounces of silver per ton. Idahoian Mine, Alturas County, Idaho. (54996.)
- (7) Sulphide ore, galena in ferruginous quartz, showing some decomposition. Santa Barbara Mine, New Mexico. (54997.)
- (8) Mixed ore, as charged into the blast furnace, made up of a large number of ores, and consisting essentially of galena with a little blende and pyrite and some decomposed material. (54998.)

The oxidized ores are represented by four specimens from the Viola Mine, Grant County, New Mexico.

- (1) Cerussite, crystallized, stained with oxide of iron. (55000.)
- (2) Cerussite, fine grained, stained with oxide of iron. (65172.)

(3) Cerussite, crystallized, stained with oxide of iron and showing a little unaltered galena. (55173.)

(4) Cerussite, stained with oxide of iron; crushed sample taken from a large amount of ore for assay; containing 64 per cent. of lead and 14 ounces of silver per ton. (54999.)

(1) A sample of litharge from the cupel furnaces such as is charged into the shaft furnaces is shown with the ores. (55007.)

To illustrate the fluxes three samples are shown :

(1) Iron scale, consisting of a mixture of metallic iron with oxides of iron. The metallic iron acts as a reducing agent by combining with the sulphur of the galena thus setting the lead free. (55004.)

(2) Cinder, from iron puddle mill. (55006.)

(3) Limestone. (55001.)

(1) A single sample of Connellsville coke illustrates the fuel used. (55003.)

Eight samples of the products of the blast furnace smelting are shown :

(1) Base bullion, containing the silver and lead of the charge, together with some impurities. (55009.)

(2) Slag, clean; too poor in lead and silver to be utilized, is thrown away. (55011.)

(3) Slag, rich; containing sufficient lead and silver to be resmelted. The production of this rich slag is avoided as much as possible. (55008.)

(4) Matte, No. 1. A by-product of the smelting operation which is drawn off with the slag and settles to the bottom of the pot. Consisting of various sulphides, especially iron, and containing most of the copper of the charge. (55013.)

(5) Matte, crushed and roasted in reverberatory furnace to remove the sulphur so that it can be recharged into the furnace. (55016.)

(6) Matte, No. 2, or concentrated; produced when charging roasted first matte. Contains sufficient copper to be smelted for that metal and is sold to other works for this purpose. (55018.)

(7) Speiss, a by-product, consisting mainly of arsenide of iron, thrown away. (55014.)

(8) Flue dust, consisting of material carried over by the blast and collected in the dust chamber attached to the furnace. (55015.)

The illustrations of the refining process are :

(1) Dross, taken from the softening furnace; consisting of the unfused impurities of the base bullion with some metallic lead. Taken from the furnace as soon as the lead is melted. (55019.)

(2) Litharge, from the concentrating cupel; consisting of oxide of lead formed during the oxidation of the lead in concentrating the silver-lead alloy. (55021.)

(3) Bottom of concentrating cupel, charged with litharge. (55024.)

(4) Litharge, from finishing cupel; oxide of lead formed in removing the lead from the silver. (55023.)

(5) Scums, from the refining furnace; formed in removing the zinc from the desilverized lead. (55027.)

(6) Lead, soft or market lead. The final result of the process, which is sold for consumption. (55026.)

LEAD ORES.

THE SOUTHEASTERN MISSOURI LEAD REGION.

This is one of the oldest and best known mining regions in the country. The first mining operations were carried on in 1720 by the famous Law Company, of Paris. As the lead is found near the river, the

facilities for working even in those days were good, and during the last century a considerable amount of lead was extracted, but like all other regions it has its ups and downs, and at present it is only by the utmost care and economy that the mines can be profitably worked. The ore consists of galena scattered through magnesian limestone, and is technically known as disseminated ore. The ore bodies occur in irregular and often very large masses, but there is no distinct line of demarcation between the ore and the barren limestone. The galena is accompanied by pyrite, and occasionally by chalcopyrite, and these generally carry cobalt and nickel. Blende is occasionally found. The amount of silver in the ore is not sufficient to be of any value, varying from 1 to 4 ounces per ton.

The active mines are mostly found in Madison, Jefferson, Washington, and St. François Counties, the most important being the St. Joe and Desloge, Bonne Terre, St. François County, and Mine La Motte, Madison County. The Valle Mine, St. François County, produces a considerable amount of zinc.

Owing to the peculiar nature of the ore, a large part of it has to undergo an elaborate system of mechanical dressing to separate the galena from the limestone. The system of dressing at each of the large works differs in material points from the others, and two of them are very fully illustrated by the collections.

The Desloge mill is very large, and is calculated to treat 300 tons of rock per day. The ore passes through Blake crushers and then through rolls, and is afterwards carefully classified, so that each set of jigs treats a material of very uniform size, differing from each other set. In the St. Joe mill, after passing the crushers, the ore goes through but one pair of rolls, and the material is fed direct to the jigs without any classification at all.

The product of these dressing operations consists of very pure galena, commonly called "mineral," and a mixture of pyrite and galena, commonly called "sulphur." The galena carries from 70 to 75 per cent. of lead, the following being actual determinations: St. Joe, September 10, 1884, lead, 71.36 per cent.; Mine La Motte, February, 1880, lead, 77.43 per cent.; January, 1881, lead, 72.12 per cent.; iron, 2.37 per cent.; cobalt and nickel, 1.51 per cent.; copper, 0.92 per cent.; insoluble residue, 1.39 per cent. The following analyses represent the composition of the sulphides:

Sulphides.

	St. Joe.	Mine La Motte.			
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Lead (Pb)	21. 87	17. 17	13. 34		0. 98
Iron (Fe)	16. 21		44. 24		40. 60
Cobalt and nickel (Co and Ni)	0. 61	4. 77	4. 07		0. 71
Insoluble residue			3. 58		4. 40
Sulphur (S)			20. 37		41. 18
Analysts	Setz.	Neill.	Neill.		Neill.

TREATMENT OF THE ORE.

Formerly the lead was extracted in Flintshire and Scotch hearths, small reverberatory furnaces, which treat from 1 to 2 tons of galena, and produce lead at a single operation. They had the advantage of being inexpensive and suited to small mines; even farmers frequently owned them and worked them at odd intervals. They were, however, very crude and wasteful, as is well illustrated by the following analysis of the slag produced:

Flintshire "Grey Slag" Desloge.

	Per cent.
Silica (SiO_2)	8.3
Protoxide of iron (FeO)	10.2
Lime (CaO)	16.0
Magnesia (MgO)	4.0
Sulphur (S)	4.5
Lead (Pb)	32.5

At present the metallurgical operations are much more complex, and are carried out on a much larger scale. The galena is first roasted in large Frieberg hearths, which are low reverberatory furnaces 66 feet long and 12 feet wide, to oxidize the sulphur. The galena, in 500-pound lots, is charged into the end nearest to the stack, and as the sulphur oxidizes it is moved along towards the hearth. When it reaches the hearth the sulphur should be reduced to from 4 to 6 per cent., and as soon as this condition is attained sand is thrown upon it in order to sinter the mass, so that it can be withdrawn and readily handled. The following analyses represent the roasted mineral:

Roasted mineral.

	Lead (Pb)	Iron (Fe)	Cobalt and nickel (Co & Ni)	Sulphur (S)	Lime (CaO)	Silica (SiO_2)	Insoluble residue.	Analyst.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	
Desloge	64.30	2.88	.....	6.00	1.90	13.09	.....	Hoffman.
St. Joe, Sept. 13, 1884	69.30	.....	.....	5.68	.....	.....	.....	Setz.
St. Joe	69.62	.....	.....	4.23	.....	.....	.....	Setz.
Mine La Motte :								
Dec. 30, 1880	71.85	3.02	.....	7.12	2.25	2.80	.....	Neill.
May 31, 1881	75.95	4.50	1.11	7.41	0.76	7.21	.....	Neill.
Nov. 1, 1881	69.77	6.12	.....	4.24	.....	.....	8.12	Neill.
Jan. 25, 1882	72.73	4.24	.....	4.35	1.94	.....	6.12	Neill.
May 15, 1882	68.40	5.60	.....	4.71	4.00	.....	8.92	Neill.

The roasting of the sulphides is a more rapid and easier process than roasting the galena on account of the iron they contain. They are thrown in one-half to one-third the way down the furnace, and when the roasting is complete are withdrawn without sintering. The following analyses represent the roasted sulphides:

Roasted sulphides.

	Dealogs.		St. Joe.		Mine La Motte.	
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Iron (Fe)	17.39	16.63	23.82	21.91	44.37	17.50
Lead (Pb)		15.42	18.46	30.74	12.58	28.00
Copper (Cu)					0.97	10.23
Nickel and Cobalt (Ni and Co)				0.98	4.07	5.30
Lime (CaO)	10.34	34.18		16.25	3.57	3.00
Magnesia (MgO)		17.83		8.11	1.25	1.65
Sulphur (S)	15.12	6.36	7.41	8.96	7.12	9.50
Insoluble residue						14.19
Analyst	Monell.	Setz.	Setz.	Setz.	Neill.	Neill.

The roasted ores are reduced in a cupola furnace. There are two kinds of smelting. In the first puddle mill cinder is employed as an iron flux, and pig lead, first matte, and slag are produced. In the second class of smelting roasted matte is used for the iron flux, and at the same time mattes richer in cobalt and nickel and copper are produced. This concentrating of the matte is continued until it contains sufficient cobalt and nickel to be shipped away for the smelting and refining of these metals.

The charge of the furnace is generally calculated to give a slag containing 30 per cent. silica, 40 per cent. protoxide of iron, 20 per cent. oxide of calcium, and 10 per cent. of other constituents, but these vary a little. Sufficient iron is also added to form matte with the sulphur of the ore.

The slags produced at the different works and in the different characters of smelting are represented by the following analyses:

Ore slag.

	St. Joe.	Mine La Motte.	
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Silica (SiO ₂)	33.67	24.00	35.30
Alumina (Al ₂ O ₃)	3.56	9.04	5.50
Protoxide of iron (FeO)	39.32	45.36	35.90
Lime (CaO)	16.21	11.20	13.90
Magnesia (MgO)	6.64	3.29	9.27
Lead (Pb)	0.53	2.75	.....

Matte slags.

	St. Joe. 1st.	Mine La Motte.			
		1st.	2d.	2d.	3d.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Silica (SiO ₂)	31.41	28.20	35.27	38.20	39.34
Alumina (Al ₂ O ₃)	2.13	7.10	1.97	13.10	
Protoxide of iron (FeO)	48.58	40.00	36.36	33.00	22.38
Lime (CaO)	11.43	11.40	14.14	8.90	18.53
Magnesia (MgO)	4.88	6.00	9.43	6.00	12.28
Sulphur (S)				2.56	
Nickel and cobalt (Ni and Co)	0.81	1.70	0.71	1.46	2.26
Lead (Pb)		1.50	1.74	2.30	2.22

The pig lead produced by the cupola smelting contains considerable subsulphide of lead and has to be refined.

The composition of the different mattes varies greatly, especially as regards the amounts of the more valuable metals, cobalt and nickel and copper, they contain, as is well illustrated by the following series of analyses made by Mr. Neill from the Mine La Motte works.

Roasted first matte.

	1.	2.	3.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Nickel and cobalt (Ni and Co)	3.12	3.66	.....
Copper (Cu)	1.79	1.05	.....
Lead (Pb)	13.68	7.96	17.54
Iron (Fe)	46.44	58.14	45.00
Sulphur (S)	6.34	3.09	8.21
Insoluble residue	3.76	3.24	3.08

Raw second matte.

	1.	2.	3.	4.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Nickel and Cobalt (Ni and Co)	12.88	6.51	3.89	12.31
Copper (Cu)	4.33	2.25	1.04	2.60
Lead (Pb)	33.50	23.96	23.37	29.52
Iron (Fe)	28.47	48.05	40.80	26.98
Sulphur (S)	18.15	16.52	.....	.....
Insoluble residue	0.36	0.46	trace.	.....

Raw third matte.

	1.	2.	3.	4.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Nickel and Cobalt (Ni and Co)	20.19	11.18 to 9.98	17.01	15.22
Copper (Cu)	7.15	7.27	6.75	4.31
Lead (Pb)	36.77	36.16	20.69	39.15
Iron (Fe)	14.45	15.74	29.74	21.61
Sulphur (S)	23.68	20.59	.....	.....
Insoluble residue .....	.....	.....	0.42	0.50

Slag which was made in the smelting of this last third matte is represented by the last slag analysis above.

This region is represented by two very complete collections, made by Mr. J. F. Kemp, M. E., September, 1884.

ST. JOE LEAD WORKS.

The product of the mines is illustrated by the following specimens of the ore:

- (1) Galena, with a little limestone, rich lump ore. (54884.)
- (2) Galena, in cleavable calcite. (54887.)
- (3) Galena, in compact limestone, characteristic disseminated ore. (54886.)
- (4) Galena, in granular limestone, characteristic disseminated ore. (54885.)

The disseminated ore is treated in the concentrating mill, as shown by the following scheme, figure 4:

The material remaining on the top of the sieves "heads" is here called "scrapings," that passing through is called "hutchwork," while the tails are called "chats."

The ore from the mines is delivered to eight 15-inch by 9-inch Blake crushers; from these it goes to eight 14-inch by 30-inch Cornish rolls, and thence passes over 7-millimetre screens. The coarse material is returned to the rolls, while the fine is washed to centrifugal pumps by a stream of water. These pumps force the material to an ingenious distributor, which delivers it, without any sorting as to sizes, to the piston jigs. There are thirty-six of these jigs in two rows of eighteen each, each jig having two sieves. The heads from the first sieve of these jigs, called scrapings, is good mineral. The hutchwork passes to a settling box, the settlings of which are purified in an ingenious screw-washer, yielding good mineral, and washings which are united with the settlings from No. 2 settling-box, and go to eighteen eccentric jigs, with 3 sieves each, yielding almost entirely hutchwork. The settlings from boxes Nos. 3 and 4 are treated on percussion tables. The overflow from sieve No. 1 of the piston jig goes to sieve No. 2, yielding scrapings of pyrite, which are recrushed, hutchwork and tailings which are known as chats. The mill treats about 800 tons of ore per day, yielding about 100,000 pounds of dressed mineral. The various steps in this process are illustrated by the following specimens:

- (1) Feed for piston jig. (54931.)
- (2) Scrapings from piston jig, sieve No. 1, mineral. (54932.)
- (3) Hutchwork from piston jig, sieve No. 1. (54925.)
- (4) Mineral from screw-washer. (54922.)
- (5) Feed for eccentric jig, sieve No. 1. (54929.)
- (6) Hutchwork from eccentric jig, sieve No. 1. (54928.)
- (7) Hutchwork from eccentric jig, sieve No. 2. (54930.)
- (8) Mineral from bump tables. (54934.)
- (9) Scrapings from piston jig, sieve No. 2. (54926.)
- (10) Hutchwork from piston jig, sieve No. 2. (54927.)

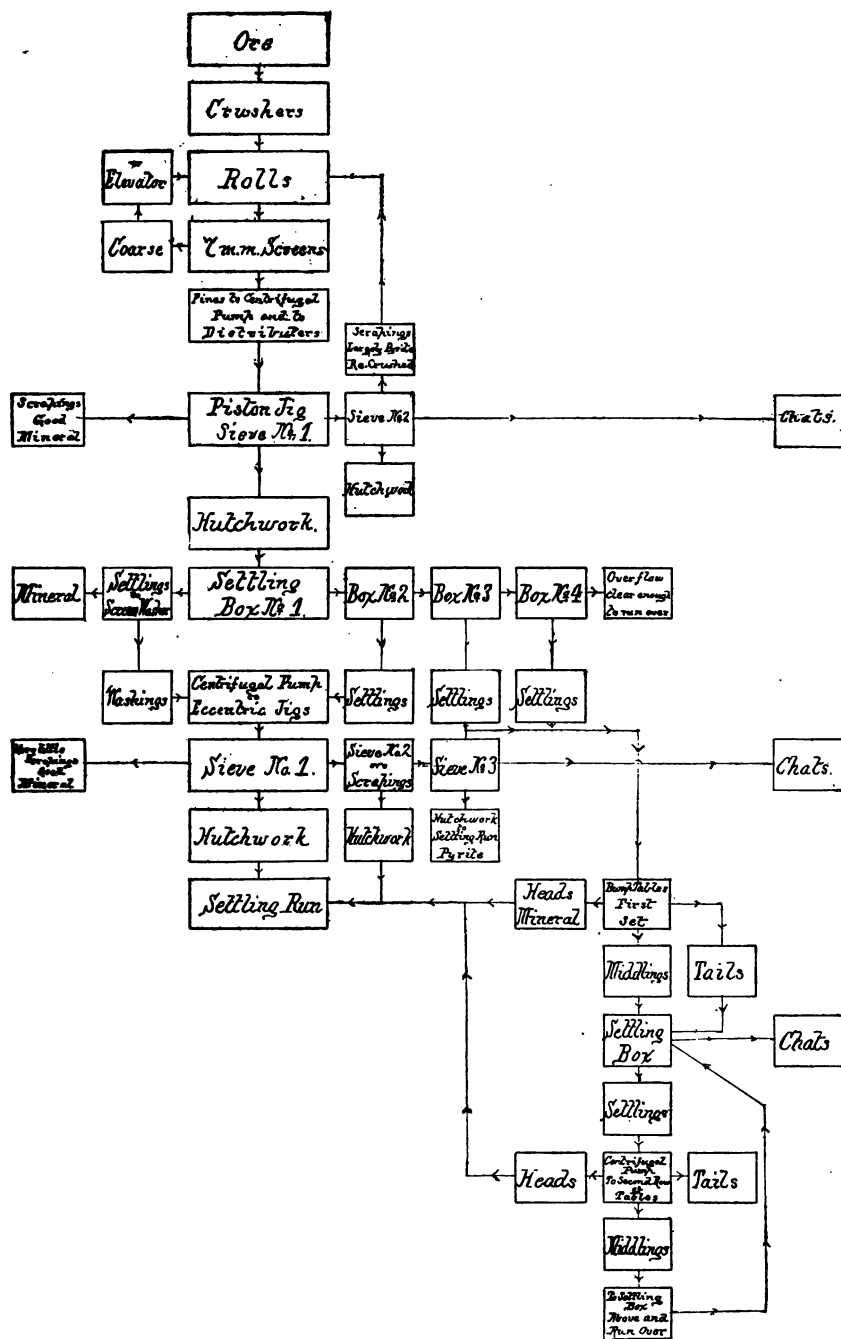


Fig. 4.
Scheme showing the operations of the St. Joe Mill.

The metallurgical treatment is illustrated by the following specimens:

Ore.

- (1) Roasted mineral. (54912.)
- (2) Roasted sulphides. (54923.)

Fuel.

- (1) Coke from West Virginia. (54902.)

Flux.

- (1) Cinder from an iron puddling furnace. (54908.)

Intermediate products.

- (1) Pig lead, unrefined, from blast furnace smelting. (54875.)
- (2) Slag, from the blast furnace smelting. (54907.)
- (3) First matte. (54905.)
- (4) First matte, roasted. (54935.)
- (5) Second matte. (54906.)
- (6) Second matte, roasted. (54916.)
- (7) Partially roasted second matte, coated with sublimed sulphur. (54920.)
- (8) Third matte. (54911.)
- (9) Third matte, roasted. (54915.)

Products.

- (1) Nickel and cobalt matte. (54918.)
- (2) Refined pig lead. (54876.)
- (3) Skimmings from the refinery. (54909.)

DESLOGE LEAD WORKS.

The product of the mine is illustrated by the following specimens of the ore:

- (1) Galena, with a little pyrite and limestone, rich lump ore. (54880.)
- (2) Galena, with very little pyrite and limestone, very rich lump ore. (54881.)
- (3) Galena and pyrite, in limestone, characteristic disseminated ore. (54882.)

The disseminated ore is treated in the concentrating mill as shown by the following scheme, figure 5.

The material remaining on the top of the sieves "heads" is here called "scrapings," that passing through is called "hutchwork," while the "tails" are called "chats."

The ore from the mine is delivered to three 15-inch by 9-inch Blake crushers; from these it goes to three 14-inch by 30-inch rolls and then to a 9-millimetre screen. What passes over this screen goes to three 14-inch by 30-inch rolls to be recrushed. What goes through the 9-millimetre screen goes to a 7-millimetre screen. What passes over this screen goes to the coarse jigs. There are three pairs of 2-sieved, end lever jigs, and one 4-sieved Collom jig, yielding scrapings, good mineral, and hutchwork, which is recrushed. The overflow from the first

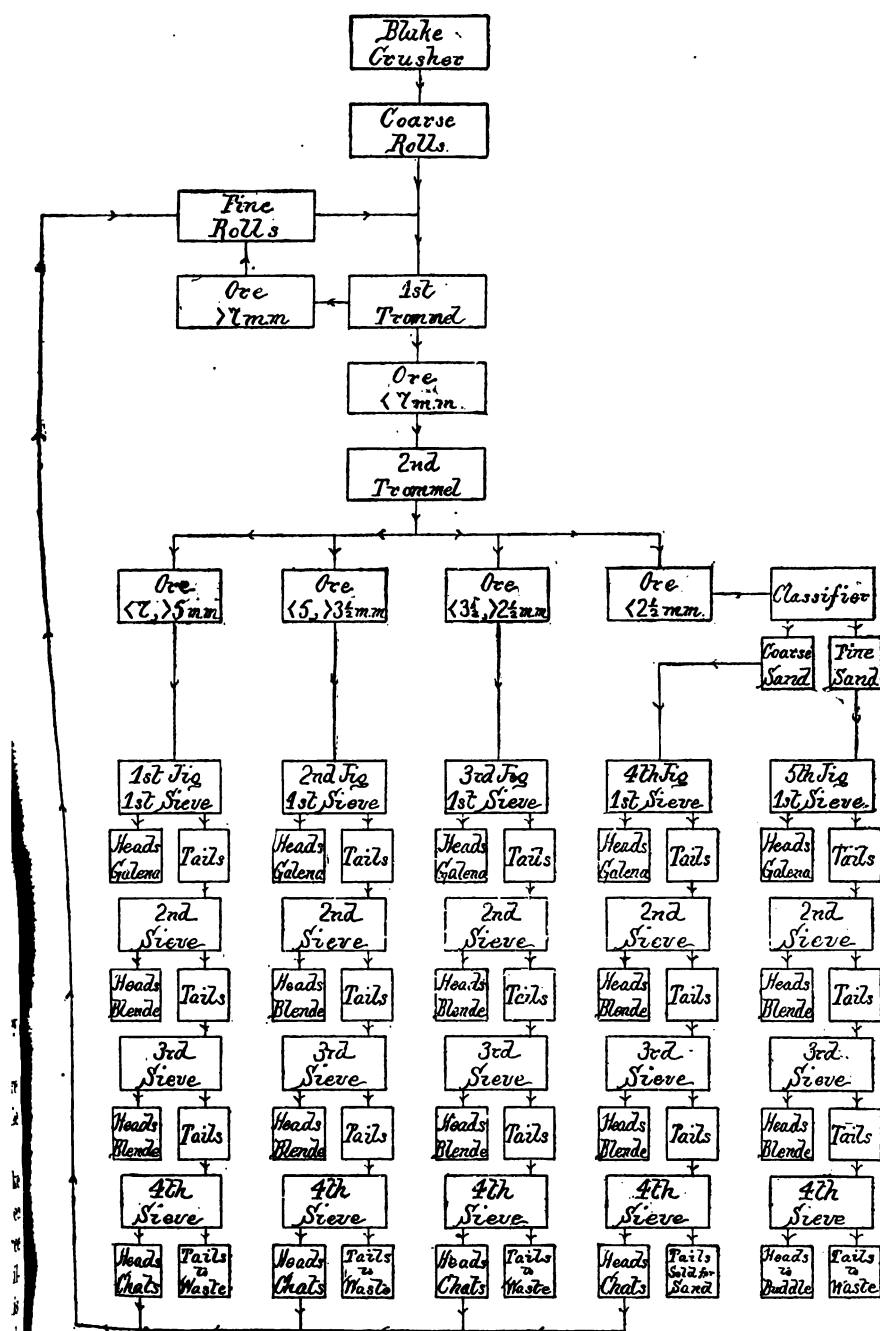


Fig. 5.

Scheme showing the operations of the Desloge Mill.

sieve goes to the second sieve, yielding scrapings which are recrushed, hutchwork, sometimes recrushed, sometimes sent direct to No. 3 jigs, and chats. The material passing through the 7-millimetre screen goes through a series of five hydraulic classifiers. The settlings from the first classifier go to the second set of twelve 2-sieved jigs, yielding from the first sieve scrapings, good mineral, and hutchwork, sometimes sent to third jigs, but with rich rock is good mineral, from the second sieve scrapings sent to recrushing rolls, hutchwork to third sieves, and chats.

The settlings from second and third classifiers go to the third set of eight 3-sieved eccentric jigs, yielding from the first sieve scrapings and hutchwork, good mineral. From second sieve scrapings, pyrite, and hutchwork, retreated on faster jigs. From third sieve scrapings, sent back to first sieve, or with rich rock, pyrite, hutchwork, retreated on faster jigs, and chats. The settlings from the fourth and fifth classifiers are treated on slime tables.

The various materials sent to the recrushing rolls are treated after crushing in the fourth set of eight 3-sieved jigs, yielding from the first sieve scrapings and hutchwork, good mineral. From second sieve scrapings, pyrite, and hutchwork sent to the old mill. From third sieve scrapings, pyrite, and hutchwork sent to the old mill, and chats.

The old mill treats the hutchwork from the second and third sieves of the fourth set of jigs, and rich chats from the main mill. The material is first crushed and then passes through a 3-millimetre screen and the coarse material recrushed. The fine stuff goes to a hydraulic classifier, the settlings from which, 3 to 1 millimetre, go to the first of two 2-sieved end lever jigs and two 3-sieved eccentric jigs. These yield from the first sieve scrapings and hutchwork, good mineral, from the second sieve scrapings, pyrite, and hutchwork, from third sieve scrapings, pyrite, hutchwork, and chats.

The overflow from the classifier carrying fine material is treated on slime tables, yielding as end products heads, good mineral, and tails, rejected.

The various steps in this process are illustrated by the following specimens :

- | | |
|---|--|
| (1) Hutchwork, jig A, sieve 1. (54938.) | (8) Hutchwork, jig C, sieve 2. (54958.) |
| (2) Hutchwork, jig A, sieve 2. (54942.) | (9) Scrapings, jig D, sieve 1. (54946.) |
| (3) Scrapings, jig B, sieve 1. (54944.) | (10) Hutchwork, jig D, sieve 1. (54941.) |
| (4) Hutchwork, jig B, sieve 1. (54948.) | (11) Scrapings, jig D, sieve 2. (54939.) |
| (5) Scrapings, jig C, sieve 1. (54962.) | (12) Scrapings, jig D, sieve 3. (54950.) |
| (6) Hutchwork, jig C, sieve 1. (54949.) | (13) Chats, jig D, sieve 3. (54960.) |
| (7) Scrapings, jig C, sieve 2. (54947.) | |

The metallurgical treatment is illustrated by the following specimens :

- (1) Roasted mineral. (54896.)
- (2) Roasted sulphides. (54940.)

Ore.

Flux.

- (1) Cinder from iron puddling mill. (54892.)

Fuel.

- (1) Coke. (54901.)

Intermediate products.

- (1) Pig lead, unrefined, from blast furnace smelting. (54877.)
 (2) Slag, from the outside of a pot full. (54893.)
 (3) Slag, crystallized, from the interior of a pot full. (54890.)
 (4) Matte. (54894.)
 (5) Roasted matte. (54899.)
 (6) Roasted matte. (54895.)

Products.

- (1) Nickel and cobalt matte, contains 9.86 per cent. nickel, 3.22 per cent. cobalt. (54921.)
 (2) Pig lead, refined. (51128.)
 (3) Skimmings from the refinery. (54898.)

THE PRODUCTION OF PIG LEAD AND WHITE PAINT AT THE LONE
ELM WORKS.

These works are situated at Joplin, Jasper County, Missouri, 1½ miles northwest of the town, and are connected with the St. Louis and San Francisco Railroad by a branch track. They are shown on PL. IX. The ore treated is mined in the immediate vicinity, and consists essentially of galena, with some blende and chert, the galena being sometimes more or less decomposed. The ore is roughly dressed at the mines. A mixture of the ore with raw coal and slacked lime is charged into a large Scotch hearth which is kept very hot, the object being to produce as much fume as possible. The products of this operation are pig lead, which is refined and sold, pasty slags containing oxidized compounds of lead, lime, and chert, which are afterwards treated for the lead they contain, and the fume. This latter is drawn off by an exhaust fan through settling chambers and cooling flues, and collected in bags made of unwashed wool. It is an impalpable powder of a lead color, and is known as blue powder. From the collecting bags it is drawn off onto a brick floor.

This material contains sufficient carbonaceous matter and unaltered sulphides to burn when ignited, and burning converts it from a light impalpable powder, difficult to handle, into an open, porous crust sufficiently coherent to stand the subsequent handling.

This crust is next thrown upon a very hot coke fire, in a slag eye furnace. This treatment gives a fume in the form of a perfectly white powder, which is drawn off and collected as before. The purified fume forms an excellent paint, and is in much demand for that purpose.

In the slag eye furnace are also treated the pasty slags from the hearth, and some carbonate of lead, locally known as "dry bone."

Besides the fume, the slag eye produces a dirty metallic lead, which is refined and sold, and slags sufficiently poor in lead to be thrown away. This operation is very fully illustrated by the following collection made by Mr. E. B. Kirby, E. M., October, 1884.

SCOTCH HEARTH SMELTING.

Ores.

- (1) Galena, with a little blende and chert, lump ore. Short Creek Mine. (55159.)
- (2) Galena, showing some decomposition, with a little blende and chert. Lump ore. (65246.)
- (3) Galena, with a little blende and chert, ready for the hearth. Dressed ore and mineral. (55160.)

Fuel.

- (1) Bituminous coal; used for the hearth and boilers. (55162.)
- Analyzed by the writer it gave:

	Per cent.
Water	2.36
Volatile matter	34.50
Fixed carbon	59.37
Ash (pink and white)	3.77
	<hr/> 100.00
Sulphur	2.42

Flux.

- (1) Slaked lime, made from limestone, 6 miles south of Joplin. Used to stiffen the slags in the Scotch hearth so that they can be easily worked. Freshly burned it contains 97 per cent. Ca O. (55163.)

Analyzed by the writer it gave:

	As received. Per cent.	Calculated to quicklime. Per cent.
Loss on ignition	30.07	.....
Insoluble residue	1.52	2.16
Oxides of iron and alumina ((FeAl) ₂ O ₃)	0.28	0.40
Lime (CaO)	68.07	96.92
Magnesia (MgO)	0.36	0.51
	<hr/> 100.30	<hr/> 99.99

Intermediate products.

Six samples of the first flue dust are shown. This dust is very complex in its composition, and varies somewhat according to where it is deposited; it consists of oxidation products together with unaltered sulphides of lead and zinc, some quicklime, carbonaceous matter, and other constituents of the charge. In some cases there has been only a small amount of oxidation of the sulphides.

- (1) From half way between the hearth and the fan. (55165.)
- (2) From first dust chamber. (55164.)



GENERAL VIEW OF THE WORKS OF THE LONE ELM COMPANY, JOPLIN, JASPER COUNTY, MISSOURI.
(See explanation, page XIII.)

These two samples on analysis by the writer showed:

	55165.	55164.
	<i>Per cent.</i>	<i>Per cent.</i>
Insoluble residue (SiO_2)	2.54	6.48
Sulphide of Lead (PbS)	10.41	51.59
Sulphide of zinc (ZnS)	0.11	5.57
Sulphate of lead (PbSO_4)	61.39	19.45
Oxide of lead (PbO)	11.47	3.79
Oxide of zinc (ZnO)	0.42	0.35
Sesquioxide of iron (Fe_2O_3)	0.97	0.50
Alumina (Al_2O_3)	0.05	0.06
Lime (CaO)	5.24	6.40
Magnesia (MgO)	0.03	0.03
Carbonic acid (CO_2)	1.35	3.83
On combustion they yielded:		
Carbonic acid (CO_2)	7.38	14.41
Water (H_2O)	3.53	3.38

(3) From first hopper, first row, blue room. (55166.)

(4) From sixth hopper, second row, blue room. (55167.)

(5) From first hopper, fourth row, blue room. (55168.)

(6) From tenth hopper, fourth row, blue room. (55169.)

Composition of the blue powders analyzed by the writer:

	55166.	55167.	55168.	55169.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Sulphide of lead (PbS)	6.18	10.37	5.19	8.61
Sulphate of lead (PbSO_4)	45.34	43.55	46.88	43.57
Oxide of lead (PbO)	44.44	44.48	45.08	44.18
Zinc (Zn)	0.61	0.34	0.43	0.61
Sesquioxide of iron and alumina ($(\text{FeAl})_2\text{O}_3$)	0.10	0.05	0.07	0.07
Lime (CaO)	0.21	0.01	0.03	0.02
Silica (SiO_2)	0.17	0.11	0.12	0.14
Carbonic acid (CO_2)	0.23	0.19	0.26	0.08
Sulphurous acid (SO_2)	0.96	0.12	0.68	0.44
On combustion yielded:				
Carbonic acid (CO_2)	3.62	2.98	3.22	2.92
Water (H_2O)	2.12	1.57	2.33	1.71

(1) The roasted blue powder consists of oxidized compounds of lead, formed by roasting the blue powder. (55170).

An analysis by the writer yielded:

	<i>Per cent.</i>
Sulphate of lead (PbSO_4)	48.76
Oxide of lead (PbO)	46.82
Oxide of zinc (ZnO)	0.27
Sesquioxide of iron (Fe_2O_3)	0.32
Alumina (Al_2O_3)	0.05
Lime (CaO)	0.48
Silica (SiO_2)	0.10
Carbonic acid (CO_2)	0.90
Sulphurous acid (SO_2)	1.65
Water (H_2O)	0.31

Final products.

(1) Slag, from the hearth smelting. (55174.)

The analysis of this material presented unusual difficulties. Several attempts were made upon it without entirely satisfactory results. The figures given are the result of a very careful examination, and are given as obtained, without insisting too much that they represent the actual arrangement of the several bodies. A small amount of coal remained adhering to the slag, but it was not submitted to combustion. Analysis by the writer gave:

Residue insoluble in nitric acid.

	Per cent.	Per c
Silica (SiO_2)	1.97	
Sulphate of lead (PbSO_4)	0.24	
Sesquioxide of iron (Fe_2O_3)	1.67	
Alumina (Al_2O_3)	0.21	
Oxide of zinc (ZnO)	0.57	4
Sulphate of lead (PbSO_4)		4

Acetic acid solution.

Silica (SiO_2)	10.73	
Oxide of lead (PbO)	33.55	
Sesquioxide of iron (Fe_2O_3)	1.23	
Alumina (Al_2O_3)	0.57	
Oxide of zinc (ZnO)	13.96	
Lime (CaO)	11.49	
Magnesia (MgO)	0.12	71

Nitric acid solution.

Sulphide of lead (PbS)	14.73	
Sulphide of iron (FeS_2)	0.67	
Sulphide of zinc (ZnS)	3.64	15
		100

Sulphurous acid (SO_2) was not present in weighable amounts.

(2) Pig lead, from the hearth smelting. (55172.)

Analyzed by the writer it showed:

	Per c
Arsenic (As)	0.00
Antimony (Sb)	0.00
Silver (Ag)	0.00
Copper (Cu)	0.01
Bismuth (Bi)	trac
Cadmium (Cd)	trac
Nickel (Ni)	0.00
Cobalt (Co)	0.00
Iron (Fe)	0.00
Zinc (Zn)	0.00

*SLAG EYE SMELTING.**Ore.*

(1) Cerussite, called dry bone. (55176.)

Fuel.

(1) Coke, from Connellsville, Pennsylvania. (55173.)

(2) Charcoal, used in the lead basin of the slag eye in refining the lead. (55174.)

Final products.

The second series of flue dusts shows the finished white paint, collected after passing through the fire. This operation oxidizes the sulphides to sulphates, so that the final product is a mixture of sulphates, carbonates, and oxides of lead and zinc.

- (1) From middle of cooling pipes. (55185.)
- (2) From first cooling chamber. (55183.)
- (3) From second cooling chamber. (55184.)
- (4) From exhaust fan box. (55186.)
- (5) From first hopper, first row; good quality. (55187.)
- (6) From fifth hopper, first row; medium quality. (55188.)
- (7) From ninth hopper, third row; best quality. (55189.)

On analysis by the writer two samples yielded:

	55187	55189
	<i>Per cent.</i>	<i>Per cent.</i>
Sulphate of lead (PbSO_4)	65.46	64.97
Oxide of lead (PbO)	25.85	25.89
Oxide of zinc (ZnO)	5.95	6.02
Sesquioxide of iron and alumina ($(\text{FeAl})_2\text{O}_3$)	0.03	0.02
Lime (CaO)	0.02	0.02
Silica (SiO_2)	0.08	0.08
Carbonic acid (CO_2)	1.53	2.01
Sulphurous acid (SO_2)	0.04	.....
Water (H_2O)	0.69	0.85
	99.61	99.86

Byproducts.

- (1) Slag. (55178.)

Analyzed by the writer it showed:

	<i>Per cent.</i>
Silica (SiO_2)	42.10
Oxide of lead (PbO)	25.37
Protoxide of iron (FeO)	7.91
Alumina (Al_2O_3)	9.58
Nickel and Cobalt (Ni and Co)	traces
Oxide of manganese (MnO)	0.27
Oxide of zinc (ZnO)	4.48
Lime (CaO)	7.97
Magnesia (MgO)	1.66
Sulphur (S)	0.22
	99.56

- (2) Basic carbonate of lead, solid deposit from the bottom of the flue. (55181.)

On analysis by the writer it showed:

	<i>Per cent.</i>	<i>Per cent.</i>
Silica (SiO_2)	2.57	
Sulphate of lead (PbSO_4)	1.05	
Sesquioxide of Iron (Fe_2O_3)	0.80	
Alumina (Al_2O_3)	0.63	
Oxide of zinc (ZnO)	1.19	6.24

	Per cent.
Sulphate of lead (PbSO_4).....	74.17
Oxide of lead (PbO).....	8.52
Sesquioxide of iron (Fe_2O_3).....	0.40
Alumina (Al_2O_3).....	0.65
Oxide of zinc (ZnO).....	2.66
Lime (CaO).....	4.45
Magnesia (MgO).....	0.22
Silica (Soluble SiO_2).....	1.55
Sulphurous acid (SO_2).....	0.27
	<hr/>
	99.13

Accessories.

- (1) Bag, made of unwashed wool used to catch the fumes. (55190.)
- (2) Fire brick, glazed by the corrosive action of the fused lead compounds in the furnace. (55180.)

THE APPLICATION OF LEAD.

A single illustration of the application of lead is shown:

THE MANUFACTURE OF WHITE LEAD BY THE DUTCH PROCESS.

The metal is cast in small pieces and placed with the requisite amount of acetic acid in crucibles with holes in the sides. The loaded crucibles are then stacked up in large piles and covered with decomposing organic material. The acetic acid gradually dissolves the lead and then the carbonic acid given off by the decomposing organic material replaces the acetic acid, forming a basic carbonate of lead. This reaction goes on until all or nearly all the metal is converted into white lead, when the crucibles are taken down, the white lead removed and ground in oil ready for use.

This process is illustrated by a collection from the works of Harrison Bros. & Co., Philadelphia, Pennsylvania, including also some higher oxides of lead formed from the white lead.

- (1) Buckle, ready for corrosion. (55691.)
- (2) Acetic acid, used for corroding the lead. (55683.)
- (3) Crucible containing buckles of metallic lead. (55690.)
- (4) Tan bark, used to cover the crucibles during the corrosion. (55684.)
- (5) Crucible containing white lead. (55692.)
- (6) Buckle, corroded. (55693.)
- (7) White lead, ground in oil. (55685.)
- (8) White lead, finished. (55686.)
- (9) Litharge. (55687.)
- (10) Orange mineral. (55688.)
- (11) Red lead. (55689.)

C O P P E R.

COPPER MINERALS.

COPPER. (MASS COPPER.)

Composition: Cu. Copper, frequently containing a little silver, bismuth, and other metals.

It crystallizes in the isometric system, in cubes, octahedrons, dodecahedrons, and the more complex forms; twin crystals are common and frequently distorted, producing very complicated crystal masses, often arborescent, with branching at sixty degrees, frequently filiform, and sometimes in sheets of considerable size. Its most common occurrence is massive. It varies in hardness from 2.5 to 3, and its specific gravity is 8.838. It has a full metallic luster and bright red color, can be highly polished, and is malleable and ductile.

It is a very common mineral, being found over a wide extent of country. At the Lake Superior mines it is almost the only source of copper. The native copper occurs here in three distinct forms:

First, masses of free copper, amounting in some cases to many tons of metal in a single mass, the largest ever found being in the foot wall of the Minnesota Mine and weighing over four hundred tons.

Second, amygdaloid copper, which is free copper in amygdules, bunches, strings, and sheets, from microscopic size up to a few hundred pounds in weight, with rarely a large mass, disseminated in a soft amygdaloid trap-rock.

Third, conglomerate copper, which is free copper mostly in strings in a hard conglomerate of ferruginous quartz pebbles.

At some localities native copper is found forming a central core, surrounded by oxydized copper minerals. In such cases, and also at the Lake Superior mines, it is evidently the original copper mineral, but in some localities it has been formed by the reduction of other copper minerals, and is therefore a secondary copper mineral. In the latter case it is never in large amounts. To illustrate the occurrence of free copper six specimens are shown:

(1) Crystallized. Copper Falls Mine, Keweenaw County, Lake Superior, Michigan. (44181.)

(2) Mass. Central Mine, Keweenaw County, Lake Superior, Michigan. (54863.)

(3) Amygdaloid. The copper occurs in small amygdules in the rock; also in a small vein with calcite and prehnite. Phoenix Mine, Lake Superior, Michigan (5367.)

(4) Conglomerate. The copper occurs in small strings, mostly in the cementing material of the conglomerate, and is quite evenly distributed through the whole mass. The conglomerate is made up of small sized pebbles of a dark red quartz porphyry. Calumet and Hecla Mine, Calumet, Lake Superior, Michigan. (18718.)

(5) In cuprite and malachite, which have been derived from the oxidation of the metallic copper. Copper Mountain, Arizona. (33386.)

(6) Crystallized, in decomposed siliceous material. The copper has been derived from other minerals, and is secondary. Copper Queen Mine, Bisbee, Cochise County, Arizona. (56041.)

Many other illustrations of the Lake Superior copper will be found in the ore series.

CHALCOPYRITE. (COPPER PYRITE.)

Composition: CuFeS_2 . Sulphide of copper and iron, containing copper 34.6 per cent., iron 30.5 per cent., and sulphur 34.9 per cent.

It crystallizes in the tetragonal system, showing especially octahedral forms, but crystals are not common. Its most general occurrence is massive. It varies in hardness from 3.5 to 4, and in specific gravity from 4.1 to 4.3. It has a brass-yellow color and full metallic luster, but is inclined to tarnish and sometimes becomes iridescent.

Chalcopyrite is by far the most common and abundant copper mineral, being in a large majority of cases the chief product of a mine and in many instances the only copper mineral found below water level. It is therefore regarded by many as being the original source of nearly all the copper. It furnishes by far the greater part of the copper produced. It is always associated with iron pyrite, and in many cases so intimately that it is impossible to separate the two minerals; in such cases the color becomes paler with the decrease of the amount of copper present, until it closely approaches the color of iron pyrite. On exposure to air and moisture it is oxydized to sulphates, which may be removed by solution in water, or may undergo further alteration to the various oxydized copper minerals. It also occurs altered to other sulphides of copper, or copper and iron, especially above the water level. To illustrate the occurrence of chalcopyrite three specimens are shown:

(1) Crystallized, a mass of skeleton crystals showing the general octahedral habit, on solid chalcopyrite. French Creek, Chester County, Pennsylvania. (65144.)

(2) Massive, showing the characteristic yellow color, somewhat darkened by tarnish. Mineral Hill Mine, Carroll County, Maryland. (17303.)

(3) With quartz, shows the characteristic iridescent tarnish. Cornwall Mine, Ste. Genevieve, Missouri. (66429.)

BORNITE. (ERUBESCITE, PURPLE OR HORSE-FLESH COPPER ORE.)

Composition: $\text{Fe Cu}_3\text{S}_3$. Sulphide of copper and iron, containing copper 55.58 per cent., iron 16.36 per cent., and sulphur 28.06 per cent. The relationship between the copper and iron varies, and sometimes there is an excessive amount of sulphur.

It crystallizes in the isometric system, but crystals are rare. It generally occurs massive and disseminated. Its hardness is 3 and specific gravity 4.4 to 5.5. The color is reddish-brown, but it soon tarnishes on exposure to air and light and is frequently coated on the outside with carbonate of copper. The luster is bright metallic.

Bornite is a valuable ore of copper and is frequently found with the other sulphides of copper. In certain levels it is the chief product of some mines. The following specimen illustrates the occurrence of bornite.

(1) Showing the characteristic tarnish. Gagnon Mine, Butte, Silver Bow County, Montana. (66431.)

CHALCOCITE. (VITREOUS COPPER, SULPHURET OF COPPER, COPPER GLANCE.)

Composition: Cu_2S . Subsulphide of copper, containing copper 79.8 per cent. and sulphur 20.2 per cent. It crystallizes in the orthorhombic system, showing especially the basal, unit prism, unit and several other octahedrons, brachy pinacoid, and several brachy dome planes; twinning is common. The crystals are quite complex. They are, however, somewhat rare. Its most common occurrence is massive. It varies in hardness from 2.5 to 3 and in specific gravity from 5.5 to 5.8, has a lead-gray color, and full metallic luster.

Chalcocite is a very valuable ore of copper and has supplied large amounts of the metal. It generally occurs in the upper portions of a mine, and in Tennessee and Montana large masses of very pure material have been found. It is very rich in metal, which is easily extracted. Chalcocite is generally the result of the decomposition of the other sulphides of copper, and is intimately associated with them. To illustrate the occurrence of chalcocite three specimens are shown:

- (1) Crystallized. Bristol, Hartford County, Connecticut. (65145.)
- (2) Crystalline, massive; showing decomposition. New Mexico. (30140.)
- (3) Massive. Anaconda Mine, Butte, Silver Bow County, Montana. (56493.)

CUPRITE. (RED OR RUBY COPPER ORE.)

Composition: Cu_2O . Suboxide of copper, containing copper 88.8 per cent. and oxygen 11.2 per cent. It crystallizes in the isometric system, especially in cubes and octahedrons, and compounds of these; also in other complicated forms. Cubes are sometimes elongated into hair-like forms. It also occurs massive, and, when impure, earthy. It varies in hardness from 3.5 to 4, and in specific gravity from 5.85 to 6.15. The color is red of various shades and the luster is adamantine.

Cuprite is a valuable source of copper, since, besides its high content of metal, it is very easily reduced. It is, however, never found alone in sufficient amounts to constitute an ore, but is always associated with other copper minerals. It is easily affected by decomposing influences, and may be either reduced to the metal or it may be changed to the higher oxide, the carbonate, or silicate. To illustrate the occurrence of cuprite two specimens are shown:

- (1) Crystallized in octahedrons, on limonite. Copper Queen Mine, Bisbee, Cochise County, Arizona. (56046.)
- (2) Massive, showing decomposition to carbonate and silicate. Longfellow Mine, Clifton district, Arizona. (33373.)

CHRSYOCOLLA. (SILICATE OF COPPER.)

Composition very variable, as it generally contains an excess of silica, besides other impurities. It contains from 22 to 36 per cent. of copper. Occurs mostly as an incrustation or filling seams, looking very much like an enamel.

It varies in hardness from 2 to 4 and in specific gravity from 2 to 2.238. The color is pale blue, sometimes dark, and even black, from impurities. In many cases it has a clay-like appearance.

Chrysocolla occurs in many copper mines, but generally in small amounts, especially in the upper portions that have been subjected to decomposing influences. To illustrate the occurrence of chrysocolla two specimens are shown :

(1) Botryoidal form. Cornwall Iron Mine, Lebanon County, Pennsylvania. (10599.)

(2) Light colored and containing an excess of silica, filling seams, and showing the characteristic enamel-like appearance. Memphis Mine, Organ District, Doña Ana County, New Mexico. (57259.)

MALACHITE. (GREEN CARBONATE OF COPPER.)

Composition: $\text{CuCO}_3 + \text{CuH}_2\text{O}_2$. Hydrated basic carbonate of copper, containing copper oxide 71.9 per cent. (copper 57.41 per cent.), carbon dioxide, 19.9 per cent., and water, 8.2 per cent.

It crystallizes in the monoclinic system, but crystals are rare. Its most common occurrence is in the form of incrustations, showing various tuberoso, botryoidal, and stalactitic formations on the outside, while the interior is generally fibrous, and often beautifully so. The incrustation often takes place in layers. It also occurs granular and earthy from impurities. It varies in hardness from 3.5 to 4 and in specific gravity from 3.7 to 4.01. It has a bright-green color, while the luster varies from adamantine in the crystals to silky in the radiated forms and to dull and earthy in many cases. The massive specimens are frequently polished and used for ornamental purposes, but for this use its softness is a great disadvantage.

Malachite is a very important copper mineral and has yielded much metal, although it is seldom found alone in large amounts, being generally accompanied by other copper minerals. It is frequently the result of the decomposition of other minerals, and is found most abundantly at and near the surface; in fact, wherever there has been any copper mineral exposed to decomposing influences the surrounding rocks are sure to be stained with malachite, so that, while malachite is found at every copper mine, its presence is not a sure indication of the presence of copper in large amounts. To illustrate the occurrence of malachite three specimens are shown :

(1) Characteristic coating, showing the botryoidal surface and the radiated interior. Copper Queen Mine, Bisbee, Cochise County, Arizona. (56064.)

(2) Showing isolated incrustations. Eagle Mine, Loudoun County, Virginia (40366.)

(3) Massive. Yankee Mine, Graham County, Arizona. (33383.)

AZURITE. (BLUE CARBONATE OF COPPER.)

Composition: $2\text{CuCO}_3 + \text{CuH}_2\text{O}_2$. Hydrated basic carbonate of copper, containing copper oxide 69.2 per cent. (copper 55.36 per cent.), carbon dioxide 25.6 per cent., and water 5.2 per cent.

It crystallizes in the monoclinic system, showing especially the basal prism and both octahedral planes; twin crystals are common and the groups of crystals are very beautiful. It also occurs in columnar forms and massive. It varies in hardness from 3.5 to 4.25 and in specific gravity from 3.5 to 3.83. The color is bright blue of several shades and the luster vitreous, while it is transparent to subtranslucent.

Azurite occurs over a very wide extent of country and is frequently associated with malachite and other copper minerals, but it seldom occurs in large amounts. In Arizona and New Mexico, however, it is very abundant. To illustrate the occurrence of azurite two specimens are shown:

(1) Crystallized, a complicated group of crystals on massive azurite. Copper Queen Mine, Bisbee, Cochise County, Arizona. (56054.)

(2) Crystallized, twin crystals on ferruginous quartz. Longfellow Mine, Clifton district, Arizona. (33382.)

COPPER ORES.

The ores of copper may be divided into three classes: Metallic, oxidized, and sulphide ores.

The first contain copper in the metallic form and are treated by a process peculiar to themselves. They are well illustrated in the collections from the Lake Superior copper region.

The second and third classes graduate into each other and many mines produce both characters of ores at different levels. Occasionally, however, a mine will produce only sulphide ores, and many of the Arizona and New Mexico mines have produced only oxidized ores. The treatment of the two kinds of ores for the production of the metal is essentially the same, except that the oxidized ores do not have to be treated for the removal of sulphur. These varieties are illustrated in the collections from the various smelting works.

LAKE SUPERIOR COPPER REGION.

This region occupies a peninsula jutting into Lake Superior, and embraces Keweenaw, Houghton, and Ontonagon Counties, of the State of Michigan. Copper was mined here by the aborigines, and various traces of their work yet remain; but it was not until after 1840 that white men were enabled to explore the region carefully, and it was a number of years more before any active mining operations were undertaken.

The discovery of large masses of pure copper (which was very frequent in the early days) attracted a great deal of attention, and the first attempts at mining were devoted almost altogether to this material. It was found, however, that the difficulty of getting out these large masses and getting them transported to manufacturing centers was very great, and as a result the early mining was generally unprofitable. These large masses sometimes contained many tons of metal, and in order to take them out of the mine it is necessary to divide

them into suitable pieces so that they can be removed. Many arrangements have been tried for this purpose, but the only one that has been at all successful is to cut the masses up by means of chisels and hammers. This is a long, laborious, and expensive operation.

At first these masses absorbed entire attention, and no attempts whatever were made to utilize the copper that was found disseminated in small amounts in so much of the rock of the country; but after the disappointments of mining the masses more and more attention was given these disseminated ores, and methods for the extraction of copper were developed until they were made very profitable. These ores contained copper in nodules, bunches, strings, and sheets, from microscopic size up, and the fact that the percentage in the average rock is small is compensated for by treating very large amounts of the material. When the average percentage is about 1 in the soft amygdaloid ores 175,000 to 200,000 tons of rock are treated annually from single mines. The harder and conglomerate ores, like the Calumet and Hecla, yield a higher percentage of copper, but the cost of treatment is greater.

The general plan of treatment is the same at all of the mines. After the ore is taken from the mine a small amount of barren material is generally selected by hand and rejected. The ore is then crushed to a suitable degree of fineness and the copper separated from the rock by jigging, which is simply keeping the material agitated in a stream of water so that the heavy copper will settle out, while the lighter rock material will float away.

For convenience the mines are divided into three classes, according to the three characteristic occurrences of the metal.

First. The so-called mass mines, which are characterized by the occurrence of large masses of free copper, amounting in some cases to many tons of metal in a single mass. Besides these large masses these mines also carry considerable disseminated free copper, generally in a true vein.

Second. The amygdaloid mines, which are characterized by the occurrence of the free copper in amygdules, bunches, strings, and sheets from the size of a pin point up to a few hundred pounds in weight (with rarely a large mass) disseminated in a soft amygdaloid trap rock. The average percentage of copper in the ores from these mines varies from three-quarters of 1 to 2 per cent.

Third. The conglomerate mines, which are characterized by the occurrence of free copper, mostly in strings, in a hard conglomerate of ferruginous quartz pebbles. The average percentage of copper in the ores from these mines varies from 4 to 6 per cent.

The occurrence and mining of free copper in the Lake Superior region is very fully illustrated. A representative mine of each of the three varieties was selected and collections taken from each. The collections are designed to show fully the occurrence of the copper together with

its associates, and includes several sections of the mines to represent the changes of the material in going up and down and also across the formation. To these mine collections are added full illustrations of the dressing operations and some illustrations of the smelting operations.

THE CENTRAL MINE.

The Central Mine was selected to illustrate the group of mass mines, as it is one of the oldest as well as one of the most successful of these mines. It was opened in 1854, and the first year of operation produced over 67 tons of refined copper, and from that time on it has been regularly productive and profitable. It is located on the southern slope of the greenstone range, 5 miles from Eagle Harbor, on Lake Superior, from which the copper is shipped by boat.

The vein, like many other veins of this region, varies greatly in thickness, being at times 5 to 6 feet wide, and in others dwindling down to a few inches. Its general direction is north and south, and its general dip towards the east. The dip, however, is small and varies, sometimes being vertical, and sometimes even being towards the west. The filling of the vein is quite complex, and varies greatly, the principal minerals being calcite, quartz, epidote, and various zeolites. While the copper is principally found in masses, yet a considerable amount of disseminated copper is also extracted. The vein is most productive when dipping towards the east, and is much poorer when dipping towards the west or vertical. In some cases the copper is not confined to the vein itself, but extends into the walls. The vein has cut through three beds of conglomerate, and a large number of amygdaloid beds, most of which contain some copper, but only one conglomerate has been worked to any extent. The mine is opened by four vertical shafts, and a series of cross-cuts to the vein.

Whenever a mass of copper is discovered in the mine it is laid bare over its whole extent on the under side, and it is then undermined sufficiently to allow it to be blown down by a blast behind it. After the mass has been detached from the wall the rock material is removed by sledges, and when necessary by blasting. When there is a considerable amount of rock material scattered through the copper it is sometimes possible to break up the mass by blasting with dynamite, but the solid masses of copper must be cut up. The cutting tool consists of a bar of steel 2 inches wide and one-half inch thick, and of varying length, according to the depth of channel to be cut. The point is drawn down across the width and flared a trifle beyond the thickness in order to give clearance. This tool is held by one workman while another strikes it with a six-pound sledge. In this way a thin chip of copper is cut and the channel is deepened by successive cuts until a piece is separated from the mass. Great skill is required to do this cutting properly, and at the very best the progress is very slow. After a piece has been

separated it is mounted on a specially constructed truck and carried to the shaft, where it is hoisted by special machinery.

After the masses reach the surface, about 75 tons of them are placed upon a pile of wood containing about 10 cords, and the wood fired. In this way the rock that adheres to the copper is loosened, so that it can be easily removed. After this cleaning they are shipped to the refineries to be melted and converted into ingots.

Besides the ordinary ore of the vein, which consists of the vein matter with disseminated copper, the third conglomerate, cut by No. 4 shaft, has been mined to a small extent. The extraction of copper from this character of material will be fully described under the Osceola Mine and Mill.

The collection from this mine was taken by Mr. E. L. Zukoski, E. M., July, 1884, and shows a series of the mass copper, a series of the stamp copper, a series of the conglomerate ores, and a series illustrating the structure of the vein.

To illustrate the mass copper nine specimens are shown :

- (1) Large mass, showing a surface that has been cut. (54871.)
- (2) Two strips, obtained in cutting up the large masses. (54869.)
- (3) Small mass, showing some rough crystals and some silicate of copper. (54870.)
- (4) Small mass, showing rough crystals with roughened surfaces and considerable adhering vein matter. (54865.)
- (5) Small mass, a thick sheet showing some branching. (54864.)
- (6) Small mass, showing a few rough crystals and considerable adhering vein matter. (54862.)
- (7) Small mass, a string, showing rough crystals with blackened surfaces. (54868.)
- (8) Small mass, consisting of branching copper with a large amount of disseminated vein matter, representing the masses that can be blasted with dynamite. (54866.)
- (9) Small mass, similar to the above, from which most of the vein matter has been removed, showing the branching of the copper. (54867.)

To represent the vein carrying disseminated free copper, six specimens are shown :

- (1) Vein rock, mostly calcite, carrying a large amount of free copper. (54849.)
- (2) Vein rock, mostly calcite, carrying much free copper, and stained by salts of copper. (54860.)
- (3) Vein rock, a mixture of calcite and epidote, carrying much free copper. (54847.)
- (4) Vein rock, a mixture of calcite and epidote, carrying only a little copper. (54850.)
- (5) Vein rock, a mixture of calcite and epidote, stained by salts of copper. (54848.)
- (6) Vein rock, mostly epidote, with some zeolites, carrying considerable free copper. (54852.)

The third conglomerate cut by the fourth shaft, differs somewhat from the other conglomerates of the region, in that it contains a large amount of epidote rock pebbles in the ordinary ferruginous quartz porphyry conglomerate, the epidote carrying most of the copper. This ore is taken out of the mine through an incline shaft running off from No. 4 shaft at the twentieth level. The incline has been run about 600 feet,

but only a small portion of this distance was sufficiently rich to be mined. To illustrate this conglomerate six specimens are shown:

- (1) Trap rock, found in patches overlying the conglomerate. (54841.)
- (2) Conglomerate, carrying a little free copper, 200 feet down incline shaft. (54854.)
- (3) Conglomerate, carrying a little free copper somewhat oxidized, 200 feet down incline shaft. (54855.)
- (4) Red conglomerate, carrying a little free copper. (54846.)
- (5) Epidote rock, carrying considerable free copper, somewhat oxidized on the surface. (54845.)
- (6) Epidote rock, barren. (54853.)

To represent the vein at different depths and also cross-sections of the vein, the following specimens are shown. From No. 2 shaft:

- (1) Vein rock, consisting essentially of quartz and epidote, carrying some free copper. Represents the vein along the hanging wall at the 22d level, south of the shaft. (54856.)
- (2) Vein rock, barren, represents the vein for about 100 feet on the 22d level south of the shaft. (54857.)
- (3) Trap rock, from hanging wall at 24th level, south of shaft. (54842.)
- (4) Trap rock, from bottom of the shaft, 60 feet below 24th level. (54861.)

From No. 4 shaft:

- (1) Trap rock, from hanging wall at 25th level. (54840.)
- (2) Parting between the hanging wall and vein at 25th level. (54839.)
- (3) Vein rock, consisting essentially of epidote and quartz with some calcite carrying a little free copper. Vein 20 inches wide. From 25th level. (54838.)
- (4) Trap rock, from foot wall at 25th level. (54841.)
- (5) Vein rock, consisting essentially of epidote and quartz with considerable free copper. From 24th level south of shaft. (54843.)
- (6) Trap rock, from hanging wall at south end of 24th level. (54858.)

THE OSCEOLA MINE.

The Osceola mine was selected to illustrate the amygdaloid mines. It is situated in Houghton County, Michigan, and work was commenced upon it in 1873. The first work done was upon the conglomerate bed, worked by the Calumet and Hecla Company on an adjoining lot, but the bed was found to be poorer than in the Calumet and Hecla ground, and was soon abandoned as unprofitable. In 1877 work was commenced upon an amygdaloid bed 750 feet southeast of the conglomerate, which had been found to be copper bearing, and has been continued until it has been developed into a very successful mine.

The mine is not upon a true vein, but is simply upon the cupriferous portion of one of the members of the regular rock series. The outline of the deposit is very irregular, the original surface of the rock was wavy and uncertain, and that portion of the rock nearest the surface being open and porous, was much more favorable for the deposit of copper. The depth to which sufficient copper to pay for working was deposited varies greatly, while occasionally the copper penetrates the overhanging rock or hanging wall. These conditions of deposition give undulating surfaces to both sides of the deposit, and while the bed

of rock is about 50 feet thick the copper-bearing portions are from 10 to 15 feet thick.

In going across the formation we find first a dark gray, fine-grained trap rock, having an irregular jointage in four directions. Near the vein these joints are filled with brilliant sheets of copper, and this is especially so where the vein is barren. Next to this comes a variable layer, 5 to 25 feet thick, of open porous amygdaloid, the amygdules and cracks being filled by calcite, laumontite, epidote, prehnite, and various zeolitic minerals, together with metallic copper, the most abundant mineral being calcite. Beyond this layer the rock gradually changes to a close-grained compact trap, with only an occasional amygdule. Small masses are occasionally found, but they seldom exceed 100 pounds in weight. Silver often occurs on and with the copper, occasionally beautifully crystallized.

The mine is opened by four shafts that have developed it to a depth of 1,350 feet on the dip, and for a distance of 2,750 feet along its strike. The shafts follow the general dip of the bed, but owing to the irregularities they will sometimes be above, sometimes in, and sometimes below the bed, but never depart very far from it. Not only is the bed irregular, but the distribution of the copper within the bed is also irregular, so that a great deal of care and judgment is necessary in planning the work of the mine so as to keep up a continual supply of good ore, and to keep the development work ahead to provide for the future.

In the distance of 1,350 feet on the dip fourteen levels have been run off to open up and work the mine. These levels follow along the irregular contact of the amygdaloid and the hanging wall. Whenever a promising piece of ground is struck a stope is started, which is carried upwards as long as paying ore is found. If no promising ground is struck in running the levels, then winzes or risers 5 feet square are run up into the rock in order to search for the ore.

The location of these winzes is a very important matter, and every point in any way likely to give any indication of the presence and position of an ore body must be carefully studied. In some cases the first investigation would seem to indicate that a given block of ground was barren, but the subsequent working out of surrounding blocks has given new indications to work by in the barren ground, and it is again attacked, and generally successfully, although occasionally three and four attacks have been made on the same block before ore was found.

As much as possible of the drilling in the mine is done by machine drills, hand drilling being confined to exploratory work, and the working out of small bodies of ore. Nitroglycerin is used almost entirely as an explosive. As the rock is broken out at the working face it travels down the stope to the level, where it is loaded on to tram cars and hauled to the shaft; it is then hoisted through the shaft to the rock house in a skip. Nearly all the rock broken out is hoisted to the surface, and while the stopes are confined as much as possible to the copper bearing rock, yet considerable barren material has to be hoisted.

This is sorted out in the rock house, about 16 per cent. of the material hoisted being sent to the dump.

The mine skip dumps its load onto a screen of parallel bars set 4 inches apart, and most of the material passes over this screen, and falls onto the main floor. Here the material is sorted, and then crushed in Blake crushers, and the barren material rejected. Large pieces, however, have to be broken before being fed to the crushers. The material falling through the 4-inch screen, and also that from the first set of crushers, passes over a 2-inch screen. What passes over this screen is again sorted, and then crushed small enough for the stamp mill. What goes through the 2-inch screen is sent directly to the stamps.

The stamp mill is 11 miles from the mine, and the crushed ore is taken to it over a narrow-gauge railroad in cars holding about 12½ tons. In the rock house assorting the small masses are picked out, cleaned as much as possible, and then packed in barrels, and sent direct to the smelting works. This material is known as barrel work, while the material sent to the stamp mill is called stamp work.

To illustrate the general character of the deposit the following specimens are shown :

- (1) A single specimen illustrating surface copper or "float." A small mass of copper completely coated by oxidation products. (54270.)
- (2) Free copper, in rough crystals. (54281.)
- (3) Free copper, small characteristic mass. (54325.)
- (4) Free copper, heavy leaf. (54324.)
- (5) Free copper, coarsely arborescent, commonly called "horn copper." (54326.)
- (6) A very characteristic sample of the ore, showing the amygdaloids of calcite, and considerable free copper. (54316.)
- (7) A very characteristic sample of the ore, showing the calcite deposited on the copper in the amygdules. Taken from the hanging wall. (54313.)

To illustrate the association of free silver with free copper three specimens are shown :

- (1) Free silver and free copper together, both roughly crystallized. (54283.)
- (2) Free silver in calcite, separate from the copper. (54297.)
- (3) Free silver and free copper, separate, both crystallized; associated with prehnite and quartz. A characteristic sample of material found in rich copper chutes, generally carrying silver. (54296.)

Owing to the uncertainty in the lower limit of the deposit, it is sometimes impossible to tell where the barren vein rock ends and the foot wall begins, and for this reason, in the sections, the foot wall has been omitted, except where it is quite distinct from the barren vein rock.

To illustrate the bed at No. 1 shaft, the following specimens are shown. A full section of the bed at the end of the second level, 300 feet north of the shaft in a stope 80 feet high, shows—

- (1) Trap rock, from the hanging wall. (54275.)
- (2) Trap, 12 feet from the hanging wall, apparently a horse. (54280.)
- (3) Ore, 15 feet from hanging wall; amygdaloid rock with free copper. A characteristic specimen. (54279.)
- (4) Poor vein rock, from foot wall 20 feet from hanging wall; amygdaloid, containing a little free copper. (54274.)

The following specimens are from the sixth level, 350 feet north of the shaft:

- (1) Selected sample, from a rich chute 12 feet wide; amygdaloid rock, with much calcite and copper. (54306.)
- (2) Barren rock, amygdaloid, showing some calcite. (54304.)

The two following samples are from the tenth level, 300 feet north of the shaft, in a stope 40 feet high.

- (1) Trap rock, showing a few flakes of copper. (54293.)
- (2) Ore, amygdaloid with a little free copper, taken just beyond a rich chute. (54259.)

From the eleventh level south of the shaft, from a stope 40 feet high:

- (1) Ore, from 8-foot vein, amygdaloid with free copper and one small branching mass; average sample. (54262.)
- (2) Barren vein rock, amygdaloid. (54319.)

From the twelfth level, 300 feet north of the shaft, in a stope 80 feet high:

- (1) Ore, from 8-foot vein, which lies horizontal for about 12 feet; amygdaloid with considerable free copper. Rich ore. (54261.)
- (2) Barren vein rock, amygdaloid. (54260.)

To illustrate the bed at No. 2 shaft, from the south stope of the second level:

- (1) Trap rock. (54312.)
- (2) Ore, amygdaloid with some copper and considerable calcite. (54263.)
- (3) Barren vein rock, containing considerable calcite. (54305.)

At the fifth level, 30 feet north of the shaft, in a stope 40 feet high, the copper occurs in streaks, accompanied by calcite and laumontite, with rich patches of epidote rock; illustrated by the following specimens:

- (1) Trap rock. (54276.)
- (2) Ore, amygdaloid and free copper. (54264.)
- (3) Ore, epidote rock, containing much free copper. (54311.)
- (4) Barren vein rock, characteristic. (54309.)

At seventh level south of the shaft, in a high stope, the vein is 10 feet wide and illustrated by two specimens:

- (1) Ore, amygdaloid; characteristic sample, showing the calcite amygdule and free copper. (54318.)
- (2) Barren vein rock. (54265.)

At the ninth level, 100 feet north of the shaft, the vein is 25 feet wide and illustrated by the following specimens:

- (1) Ore, amygdaloid; characteristic sample, showing calcite deposited on the free copper in amygdules. (54301.)
- (2) Foot wall, slightly amygdaloidal. (54266.)

At the twelfth level, in north stope, 50 feet high, where the vein is 10 feet wide, there is a chute 12 feet wide, especially rich, next to the hanging wall, illustrated by the following specimens:

- (1) Ore, selected specimen, showing much free copper. (54315.)
- (2) Foot wall, showing many small amygdules filled with reddish laumontite. (54310.)

fourteenth level, 100 feet in the south drift:

(5427.)
 amygdaloid. (54303.)

first level, 50 feet south of No. 3 shaft:

showing sheet copper at the contact between the two beds.

containing many small amygdules, some of them filled with reddish
 (54298.)

seventh level south of the shaft a specimen is shown which
 a conglomerate of amygdaloid rock. (54269.)

twelfth level, 400 feet north of the shaft, in a stope 30 feet
 the vein is 8 feet wide:

joining the hanging wall. (54254.)

vein rock, showing small amygdules of calcite. (54255.)

twelfth level, north of the shaft, three samples of crystal-
 ler are shown. (54289.)

thirteenth level, at the north end of the drift, where the
 feet wide, and where there is a chute 15 feet broad:

epidote rock, containing much free copper. (54256.)

vein rock, 7 feet from hanging wall. (54257.)

the bottom of the shaft at the fourteenth level, directly on the

rock. (54258.)

amygdaloid containing much free copper. (54307.)

the fourth shaft, second level, 100 feet south of shaft:

up, slightly amygdaloidal, from hanging wall. (54320.)

amygdaloid with free copper. (54302.)

the fifth level south stope:

free copper, in sheets, taken from the contact between the bed and hanging
 (54291.)

ore, amygdaloid, with free copper in small amygdules, and also in sheets; sam-
 ken next to the hanging wall. (54282.)

Ore, amygdaloid with free copper; characteristic sample. (54249.)

Barren vein rock, trap with small amygdules. (54272.)

from the seventh level at the end of the drift, 650 feet south from
 shaft:

Trap rock. (54250.)

Barren vein rock, amygdaloid with amygdules filled with calcite and reddish
 nonite. (54277.)

from the ninth level, 50 feet south of shaft:

1) Trap rock. (54251.)

2) Parting from contact. (54294.)

3) Ore, epidote rock with much free copper, 5 feet from hanging wall. (54314.)

from the tenth level, 300 feet from the shaft:

1) Barren vein rock, amygdaloid with small-sized amygdules filled with calcite.

---teristic sample of a 250-foot streak of hard ground without copper, taken 2
 m hanging wall. (54253.)

(2) Vein rock, amygdaloid with medium-sized amygdules, mostly filled with calcite, but containing a few streaks of copper. Characteristic sample of promising rock taken 4 feet from hanging wall. (54285.)

From 60 feet below the tenth level, where the shaft is under the vein:

Characteristic sample of the foot wall taken 20 feet from the hanging wall. (54252.)

In prospecting from the conglomerate into the overlying trap, a series of apparently isolated irregular bodies of cupriferous amygdaloids were discovered, and this series has been called the West vein. To illustrate this vein the following specimens are shown:

- (1) Trap, containing a few good sized amygdules filled with a dark-green mineral. Represents the hanging wall of the conglomerate. (54288.)
- (2) Amygdaloid, 12 feet in the cross-cut. (54286.)
- (3) Trap rock, 20 feet in the cross-cut. (54284.)
- (4) Amygdaloid, 70 feet in the cross-cut. (54271.)
- (5) Amygdaloid, 100 feet in the cross-cut. (54292.)
- (6) Trap, 100 feet in the cross-cut, showing some thin flakes of copper. (54287.)
- (7) Barren amygdaloid, 120 feet in the cross-cut. (54317.)
- (8) Ore, amygdaloid containing considerable branching copper, 120 feet in the cross-cut. (54299.)
- (9) Two characteristic samples of the West vein ore taken from the rock house. (54290 and 54295.)

THE SEPARATION OF THE COPPER FROM THE ROCK.

After passing the final screen at the rock house, the ore is delivered to the stamp mill for further treatment. As delivered to the mill, the ore contains copper in very small masses, threads, sheets, and amygdules, from microscopic size up.

The object of the treatment in the stamp mill is, first, to crush the ore so as to liberate the copper from the inclosing rock material, and then to separate the copper from the rock by jigging in running water. The fineness of the crushing is governed by the fineness of the copper, and in general the finer the crushing the more perfectly is the copper liberated from the rock; on the other hand, the fine crushing tends to flatten the coarser copper into thin sheets, which are very difficult to catch on the jigs, so that the crushing is never carried far enough to liberate all of the copper.

Particles of rock containing copper are always found on top of the bed of the coarse copper on the sieves, since they are too heavy to be carried away by the current of water, and yet not heavy enough to settle well, and too large to pass through the sieve. This material is removed separately, and is called "ragging." It is sometimes returned to the stamps, and is sometimes treated in special apparatus.

The crushing takes place in large stamps, which are constructed so as to deliver a blow by the expansion of steam on the same general principle as a steam hammer; but this application has somewhat altered the construction, and it has been so improved that a single stamp will crush about 200 tons of rock in 24 hours so as to pass a screen with holes three-sixteenths of an inch in diameter, placed in the front and

sides of the mortar, the exit of the crushed material being aided by a stream of water. There will always be some copper in the ore too large to pass the screen, and every 8 hours the stamp is stopped and the copper is taken out of the mortar. It is known as "mortar heads."

It has not been found practical to size the crushed ore by the ordinary means, and it is only partially accomplished by hydraulic separators, which are simply long double V shaped troughs in which the ore falls against an ascending current of water. At suitable distances there are holes in the bottom of the inner trough allowing the particles of ore that have settled at different distances in the trough to pass into compartments in the space between the two troughs from whence it is drawn to feed the jigs. The first compartment will contain the coarsest and heaviest of the crushed material, and the second compartment the next coarsest and heaviest, and so on. The rock being quite regular in its shape each compartment will contain grains of about equal size, but the copper, being very irregular in size and shape, varying from spherical or cubical to very flat and thin, will vary much in the size of the grains in any one compartment. The settlings from each compartment are delivered to its own set of jigs by a stream of water.

The jigs mostly used are known as Collom plunger jigs from the fact that the material on the sieve is kept agitated by a plunger which is alternately forced rapidly down by a rocker striking the end of the piston and is slowly raised by a spring. These jigs yield four classes of products. First, ragging, particles of rock containing a little copper; second, heads, nearly pure copper; third, hutchwork, a mixture of copper and rock material that has passed through the bed of heads on the sieve; fourth, tails.

The ragging is either returned to the stamps or else treated in special apparatus. The coarse heads are sent to the smelting works, but the finer heads contain considerable rock material and are treated in keeves and buddles. The hutchwork is sent to jigs with finer sieves, the coarse tails are rejigged and the final tails dumped into the lake, while the finer tails are treated in the tail house.

The slimes that do not settle in the hydraulic separator go to settling boxes, and the settlings from these go through a complicated treatment on slime tables and in keeves and buddles, the final products being finely divided copper containing considerable foreign matter.

The Osceola stamp mill.—This mill is situated on the north shore of Portage Lake, affording the necessary supply of water, and a convenient dumping ground for refuse material. It is provided with four Ball steam stamps, fifty-four Collom jigs, five Evans slime tables, together with all the necessary adjuncts for carrying on the work successfully. The jig floor is divided into three divisions, each containing a stamp and set of washing apparatus. The fourth stamp is held in reserve, and is arranged to deliver the stamped rock to either one of the three divisions. Each division contains three hydraulic separators, each one



Fig. 6.

One division of the Osceola Stamp Mill.

of which supplies two rows of roughing jigs. There are also three rows of finishing jigs, together with the necessary settling boxes. One of these divisions of the mill is illustrated in detail by figure 6.

The crushed ore from the stamp *A* is delivered by the launder *C* to the three separators *B*, which divide it roughly into four classes, while the slimes pass on to the settling boxes. During the jigging on the head machines the copper settles out, and all that is small enough, together with some rock material, goes through the sieve to form the hutchwork. All that is too large remains on the sieve, and is taken off from time to time. About half a barrel of ragging is skimmed off during the day. The jigs *D* and *C* yield No. 1 mineral as heads; *B* sometimes yields No. 1, and sometimes No. 2, while *A* yields No. 2 mineral. The hutchwork from this set of jigs is fed to the top row of finishing sieves *M*, *L*, *K*, and *I*. The tails from the head sieves go to the first tail sieves *E*, *F*, *G*, and *H*, and are rejigged. These sieves yield three products, heads or ragging, hutchwork, and tails. The hutchwork goes to the middle row of finishing jigs *Q*, *P*, *O*, and *N*, while the tails go to the lake.

The tails from the top row of finishing jigs pass on through settling boxes to the middle row of finishing jigs, and the tails from the middle row pass through the last row. Sieves *M* and *L* yield No. 2 mineral as heads and also as hutchwork. Sieves *K*, *I*, *Q*, and *P* yield No. 3 mineral, both as heads and hutchwork. Sieves *O*, *N*, *U*, *T*, *S*, and *R* yield No. 4 mineral as hutchwork. This No. 4 mineral contains a considerable amount of rock

matter, and is purified by treating in a keeve and on buddles, according to the scheme shown in figure 7.

No. 1 copper is dried and the silver picked out of it by hand. The ragging is also dried and then sifted. The finest copper siftings are mixed with No. 4 mineral, and the coarse siftings with No. 3, while the rock containing inclosed copper is returned to the stamps.

All the mineral is packed in old oil barrels, and, with the exception of No. 1, is shipped wet, as it comes from the jigs, to the smelting works.

The slimes that will not settle in the hydraulic separators pass through four large settling boxes, and are treated according to the scheme shown in figure 8 yielding No. 3 and No. 4 copper.

The finer tails passing to the tail house are treated according to the scheme shown in figure 9, yielding No. 5 copper. This treatment in the tail house serves almost exclusively as a check upon the work of the mill, by showing when too much copper is passing out in the tails. When the mill is running properly there is not sufficient copper removed in the tail house to pay for the treatment.

To illustrate the operation of the mill twenty-three specimens are shown.

- (1) General average of the ore as sent from the rock house to the mill. (54273.)
- (2) Crushed rock, as it passes the sieves of the mortar. (51314.)
- (3) Heads from the mortar, consisting of metallic copper too large to pass the sieves. (54229.)
- (4) First-class material, from the first division of the hydraulic separator. (54218.)
- (5) Second-class material, from the second division of the hydraulic separator. (54219.)
- (6) Third-class material, from the third division of the hydraulic separator. (54220.)
- (7) Fourth-class material, from the fourth division of the hydraulic separator. (54221.)
- (8) Slimes, that pass away with the water from the hydraulic separator. (54222.)
- (9) No. 1 copper, separated on the roughing jigs. (54244.)
- (10) Ragging, consisting of particles of copper with small pieces of rock adhering to it, scraped from the surface of the copper on the sieves. (54230.)
- (11) Tails, from the roughing jigs. (54223.)
- (12) Hutchwork, from the roughing jigs treating first and second-class material from the hydraulic separator. (54225.)
- (13) Hutchwork, from roughing jigs treating third and fourth class material from the hydraulic separator. (54227.)
- (14) No. 2 copper, separated on the finishing jigs. (54245.)
- (15) Tails, from finishing jigs. (54224.)
- (16) Slimes, as fed to Evans slime tables from settling boxes. (54228.)
- (17) Heads, from Evans slime tables. (54243.)
- (18) No. 3 copper, obtained in treating the heads from the Evans slime tables in keeves. (54246.)
- (19) No. 4 copper, obtained in treating the heads from the Evans slime tables in keeves. (54247.)
- (20) Tails, from Evans slime tables. (54226.)
- (21) Tails, taken from the runs of the tail house. (54231.)
- (22) No. 5 copper, obtained by treatment of the tails in the tail house. (54248.)
- (23) Tails, from the buddle in the tail house. (54232.)

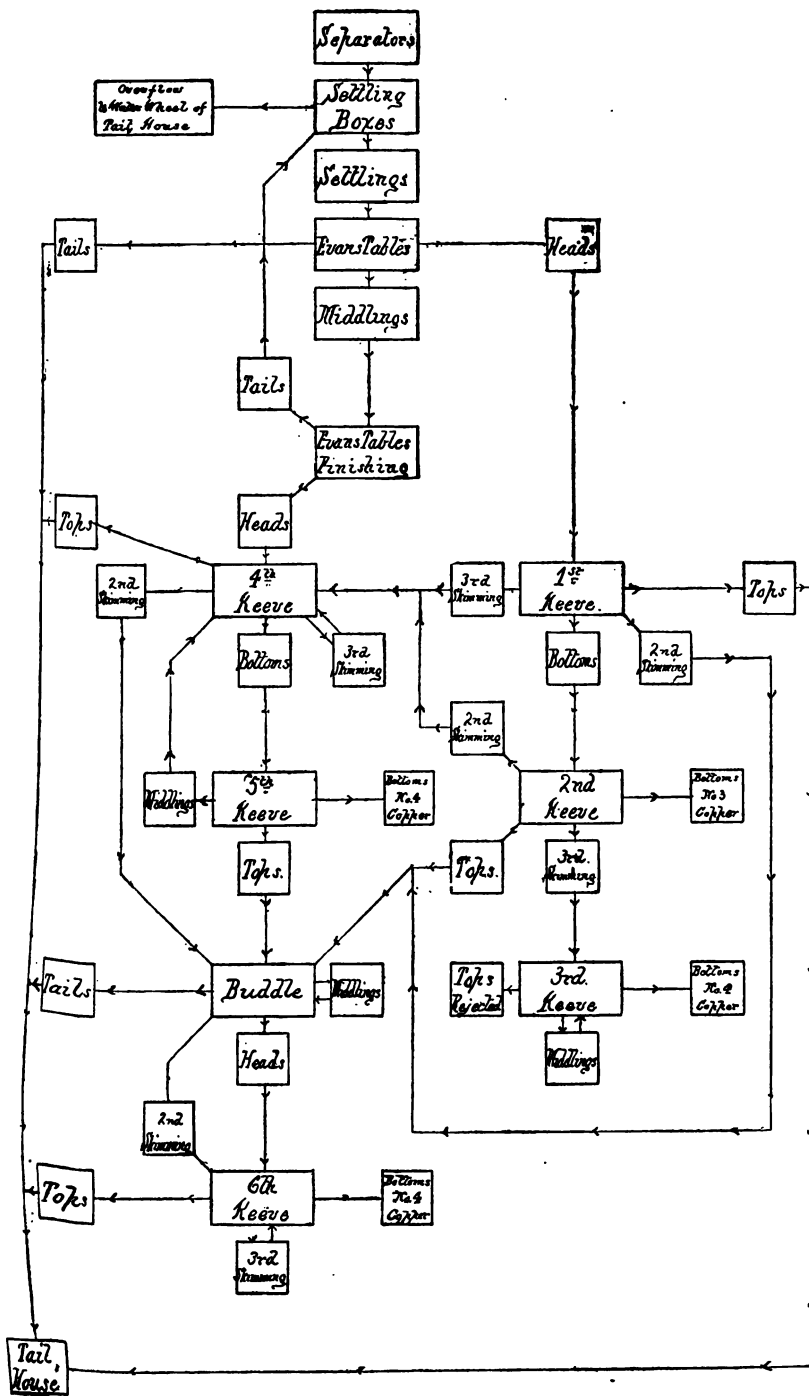


Fig. 8.
Scheme showing treatment of slimes in Osceola Stamp Mill.

THE DELAWARE MINE.

The Delaware Mine, situated in the upper part of the Keweenaw point, Michigan, 35 miles from Portage Lake, was selected to illustrate the conglomerate veins. The first workings on this location were directed to the extraction of copper from the transverse veins carrying mostly mass copper, but were unsuccessful. In 1881 attention was directed toward the conglomerate bed, and a new plant commenced for actively working it. The mine has been equipped in the best manner, and is well provided with all the machinery for extensive working. It has been opened to a depth of 1,600 feet, and for a length of 2,150 feet; it is provided with three shafts for hoisting the ore, and the general development is far in advance of the actual working.

A section of the strata at this point shows first, greenstone 500 to 600 feet thick, dipping 24 degrees to the north; then 7 feet of a shattered black trap; between this and the conglomerate there is a selvage seam of clay 2 inches thick. The conglomerate bed is 25 to 28 feet thick, and below is an amygdaloid bed 50 to 60 feet thick. Beyond this there is a succession of the ordinary country rocks.

The conglomerate is generally coarse, although it varies from a sand to boulders of a cubic foot or more. The pebbles are mostly red and brown quartz porphyrys. Occasionally, however, there are pebbles of amygdaloid, and near the base of the bed where the conglomerate is more loosely cemented, the number increases. These amygdaloid pebbles appear to have come from the bed below the conglomerate. There is a marked stratification of the conglomerate, from the variation in the size of the pebbles. The sandstone strata are generally thin, and are quite local. They appear to contain a large proportion of feldspathic material.

The copper-bearing layer of the bed is generally found within 8 or 10 feet of the base, although the first 2 feet above the foot wall is generally barren. Above this 2 feet the copper is distributed through a single layer 5 or 6 feet thick or through several thinner layers separated by barren material. Above these layers little copper is found, although small masses have been frequently found along the contact between the top of the conglomerate and the greenstone. The general character of the copper-bearing layers is the same as the barren layers, except that they are somewhat more open in structure. The copper has been deposited in the cementing material between the grains, and some of the richest material is sandstone cemented by copper. Copper has not been found in the interior of the quartz porphyry pebbles, but has been found in the amygdaloid pebbles.

Near the bottom of the bed interesting masses of copper are found which have evidently been deposited in cavities left by the dissolving out of amygdaloid pebbles. In some cases the copper forms a perfect cast of the original pebble, while in others the deposition of copper has

stopped before the cast has been completed, leaving an outside shell of copper with crystals and crystalline masses projecting into the open center.

The conglomerate bed is traversed by a great many fissures running in every direction, and causing a great deal of faulting, which adds seriously to the difficulties of mining. Some of these fissures are filled with calcite, forming true veins, while others are simply filled with clay. The faulting produced by these fissures is generally small, but owing to their number they are very troublesome. The clay fissures or slips simply fault the strata, while the calcite veins not only fault the strata, but also terminate the copper-bearing layer. Within the copper-bearing layers the copper is more or less concentrated, forming rich chutes, and there are several of these chutes.

A plan of the mine is shown in PL. X.

The following are characteristic samples of the ore :

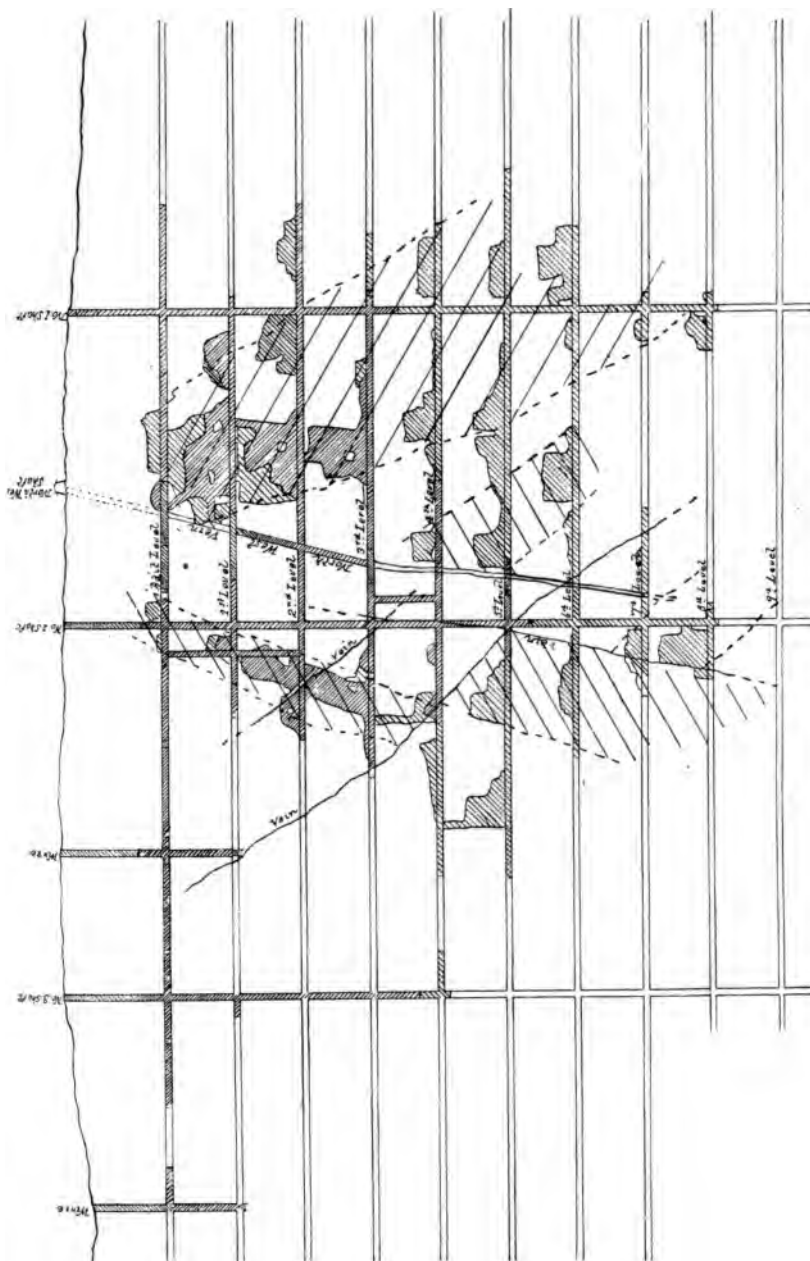
- (1) Free copper, coated with oxidation products, surface or float copper. (54743.)
- (2) Conglomerate, with much free copper. The blackened copper of this specimen is characteristic of the ore above the water level, 400 to 500 feet. (54729.)
- (3) Conglomerate, fine-grained, containing much free copper. From the eastern chute between the first and second levels. (54740.)
- (4) Conglomerate, containing much free copper which cements the pebbles. (54730.)
- (5) Conglomerate, very coarse, with free copper. (54674.)
- (6) Conglomerate, very coarse, with free copper and some calcite. (54651.)
- (7) Conglomerate, coarse, with free copper. (54726.)
- (8) Conglomerate, coarse, with free copper. (54733.)
- (9) Conglomerate, containing considerable sand with free copper. (54727.)
- (10) Conglomerate, containing much sand with much free copper. (54728.)
- (11) Free copper, a small mass. (54680.)
- (12) Free copper, coated with crystals of calcite. From one of the fissure veins. (54687.)
- (13) Trap rock, carrying a little free copper. From northwest vein, 10 inches wide. (54663.)

The following five samples represent the characteristic barren conglomerate and sandstones :

- (1) Conglomerate, ordinary, compact. (54682.)
- (2) Conglomerate, ordinary, compact, showing some calcite. (54681.)
- (3) Conglomerate, ordinary, compact, with amygdaloid pebbles. (54665.)
- (4) Sandstone, with a few pebbles, from a 6-inch layer. (54688.)
- (5) Sandstone. (54673.)

To illustrate the formations exposed by the mining operations a complete section of the bed, taken from the crosscut 160 feet east of No. 1 shaft, is first shown. The whole width of the bed at this point is about 30 feet and presents some peculiarities. It has no sandstone layers and in general is more open in the upper levels than in the deeper portions of the mine. There are two copper bearing layers or chutes, the lower one being thicker and more valuable :

- (1) Trap rock, very much decomposed and friable, from a bed 7 feet thick, between the greenstone and the conglomerate. A 2-inch streak of clay separates this trap from the conglomerate. (54689.)
- (2) Conglomerate, from the top of the bed, showing the contact. (54677.)



PLAN ON PLANE OF BELT OF THE WORKINGS OF THE DELAWARE MINE, MICHIGAN.
(See explanation, page XIV.)

About 12 feet of conglomerate of moderate size and somewhat uniform pebbles follow the contact, some of the layers being more open than others :

- (1) Conglomerate, from an open layer. (54657.)
- (2) Conglomerate, from a compact layer, showing one of the slips or fissures so common in the mine, which has faulted the bed here 5 or 6 inches. (54670.)
- (3) Conglomerate, irregular sized pebbles with free copper in the cementing material, from a 10-inch layer. Shows the generally looser structure of the cupriferous layers. (54685.)
- (4) Conglomerate, containing very large pebbles, from a 7-foot layer. (54664.)
- (5) Conglomerate, compact, from a 2-foot layer, 21 feet from the hanging wall. (54654.)
- (6) Conglomerate of large sized pebbles, with considerable free copper, from a 4-foot layer, 23 feet from the hanging wall. (54656.)
- (7) Conglomerate, 27 feet from hanging wall and 3 feet from foot wall. (54676.)
- (8) Amygdaloid, from a boulder in the conglomerate just above the foot wall. (54693.)

A section of the beds continued below the conglomerate is shown by an adit level of the northwestern vein :

- (1) Trap rock, amygdaloidal at the contact. (54671.)
- (2) Trap rock, amygdaloid, 39 feet from contact. (54662.)
- (3) Trap rock, amygdaloid, 66 feet from contact. (54704.)
- (4) Trap rock, amygdaloid, 90 feet from contact. (54675.)
- (5) Trap rock, amygdaloid, 159 feet from contact. (54700.)
- (6) Trap rock, amygdaloid, 270 feet from contact. (54678.)
- (7) Trap rock, amygdaloid, 10-foot bed, 294 feet from contact. (54655.)
- (8) Trap rock, amygdaloid, 306 feet from contact. (54724.)
- (9) Trap rock, amygdaloid, 474 feet from contact. (54653.)
- (10) Trap rock, amygdaloid, 594 feet from contact. (54701.)

The western ore body is illustrated by the following specimens taken from a stope half way between the adit and No. 1. level :

- (1) Free copper, with a little calcite, shows the impression of several pebbles, and illustrates the occurrence of the copper as a cementing material. (54669.)
- (2) Conglomerate, with much free copper, from a 12-inch layer, 7 feet from the foot wall, very loose in texture. (54698.)
- (3) Calcite, the filling of one of the fissure veins. (54697.)
- (4) Conglomerate, a large pebble showing calcite on several sides. (54703.)

A section of the bed 75 feet west of the second shaft at the seventh level is as follows : 6 inches of sandstone showing ripple marks, 4 feet of compact conglomerate, 6-inch layer of open cupriferous rock, 2 feet of compact conglomerate, 18-inch layer of very rich rock, 4 feet of compact conglomerate. This section is illustrated by samples taken east of the shaft :

- (1) Sandstone, showing north and south ripple marks. (54690.)
- (2) Conglomerate, compact and barren. (54694.)
- (3) Conglomerate, with free copper, from the 6-inch layer. (54731.)
- (4) Conglomerate, with much free copper, from the 18-inch seam. (54666.)
- (5) Trap rock, slightly amygdaloidal, from the foot wall. (54658.)

In the stope about 50 feet below the seventh level these two cupriferous layers have united, forming a layer of very rich ground, beginning 3 feet from the foot wall and being 5 feet in width:

- (1) Conglomerate, containing much free copper and considerable calcite. (54652.)
- (2) Conglomerate, compact and barren. (54699.)
- (3) Conglomerate, showing intersection of a calcite vein and a slip. (54695.)

The following specimens, although not taken at one point, represent a characteristic section of the bed:

- (1) Trap rock, from the greenstone range, between 500 and 600 feet thick at this point. (54684.)
- (2) Free copper, from the contact between the trap and the conglomerate. (54741.)
- (3) Free copper, from the contact, has been flattened out by pressure. (54737.)
- (4) Free copper, from the contact, has been flattened out by pressure. (54738.)
- (5) Conglomerate, with pebbles varying very much in size. Found only within 6 or 7 feet of the top of the conglomerate. (54667.)
- (6) Amygdaloid, from a boulder near the foot wall. (54692.)
- (7) Free copper, cast of a peculiar shaped amygdaloid pebble; from near the foot wall. (54732.)
- (8) Free copper, cast of a large flat pebble. (54735.)
- (9) Free copper, apparently the cast of several pebbles that touched each other; from near the foot wall. (54736.)
- (10) Free copper, apparently the beginning of the cast of a pebble, showing the crystalline interior; from near the foot wall. (54691.)
- (11) Free copper, cast of a pebble, with adhering conglomerate; from near the foot wall. (54739.)
- (12) Amygdaloid, much decomposed, and containing free copper; from near the foot wall. (54723.)

The Delaware stamp mill.—The treatment in the mill is nearly the same as at the Osceola mill. To illustrate the extraction of copper in the mill sixteen specimens are shown:

- (1) Conglomerate, containing free copper. Represents the average of the material sent to the mill. (54744.)
- (2) Crushed rock, as it passes the sieves of the mortar. (54712.)
- (3) Heads, from mortar; consisting of copper in pieces too large to pass the sieves. The silver in the copper is generally found in this material; it is picked out by hand and averages about 16 pounds a month. Grade No. 1, nearly pure copper. (54706.)
- (4) First-class material, from the first division of the hydraulic separators. (54719.)
- (5) Second-class material, from the second division of the hydraulic separators. (54718.)
- (6) Third-class material, from the third division of the hydraulic separators. (54721.)
- (7) Fourth-class material, from the fourth division of the hydraulic separators. (54715.)
- (8) Copper, separated on the roughing sieves. Grade No. 2, containing about 95 per cent. of copper. (54707.)
- (9) Coarse tails, from the roughing sieves. (54720.)
- (10) Fine tails, from the roughing sieves. (54714.)
- (11) Copper, separated on the finishing sieves, including the coarse material in the sieves and the fine hutchwork that has passed through. Grade No. 3, containing about 86 per cent. of copper. (54708.)
- (12) Coarse tails, from finishing sieves. (54717.)
- (13) Fine tails, from finishing sieves. (54713.)
- (14) Copper, separated from the slimes by treating them on the Evans slime tables

and tossing the heads from the last table in a keeve. Grade No. 4 B, containing about 33 per cent. of copper. (54710.)

(15) Copper, obtained from the black sands of the last row of finishing sieves, by treating them on the head buddle and tossing in a keeve. Grade No. 4 C, containing about 32 per cent. of copper. (54711.)

(16) Final tails, as discharged into the lake. (54716.)

SMELTING LAKE SUPERIOR COPPER.

The product of all the Lake Superior mines consists, according to analyses, of:

First. Mass copper cut from the large masses, being nearly pure copper.

Second. Mass copper containing considerable adhering rock matter, sometimes called kiln copper, because it has been treated in a kiln to remove as much as possible of the rock matter.

Third. Barrel copper; small masses broken from the rock and yet containing some adhering rock matter.

Fourth. Stamped copper of various grades, the coarsest being nearly pure copper, while the finer grades contain increasing amounts of rock matter, especially magnetite, and also particles of metallic iron from the stamps.

All this material has to be melted in specially constructed reverberatory furnaces and then refined to remove the iron.

C. G. HUSSEY COPPER WORKS, PITTSBURG, PENNSYLVANIA.

These works treat entirely the products of the Mass Mine, Lake Superior. 10,000 pounds are charged into a reverberatory furnace in the afternoon, a suitable mixture being made of the small masses or kiln copper and the stamped material. The charge gradually melts, and at 6 o'clock the next morning the process of refining begins. The melted metal is first oxidized to remove impurities and then poled with green wood to get "tough pitch" metal. This is generally finished about 10 o'clock, when casting begins. The refined copper is cast into long bars for rod rolling or into slabs for sheet rolling, and the entire product is consumed in the same works. The specimens include:

Ore.

- (1) A small mass, representing the barrel and kiln copper. (54972.)
- (2) Stamped copper, a mixture of several grades of stamped material. (54973.)
- (3) Stamped copper, the finest grade from the treatment of the slimes and tailings. (54974.)

Fuel.

- (1) Bituminous coal. (55209.)
- (2) Charcoal, used in the refining as a reducing agent. (54985.)

Intermediate products.

- (1) Copper, taken from the bath before beginning to rabble. (54975.)
- (2) Slag, first skimming. (54980.)
- (3) Copper, taken from the bath after rabbling. (54976.)

- (4) Slag, second skimming. (54981.)
- (5) Copper, taken just before poling. (54977.)
- (6) Slag, third skimming. (54982.)
- (7) Copper, taken from the bath after the skimming during the poling. (54978.)
- (8) Slag, skimmed after poling. (54983.)
- (9) Test piece, a small sample taken from the bath and hammered, in order to test its quality, just before beginning to cast. (55211.)

Final product.

- (1) Ingot. (54979.)

Accessories.

- (1) Sand, used for making the furnace bottom. (55210.)
- (2) Pole, hickory, used to deoxidize the copper bath. (54984.)

THE LAKE SUPERIOR NATIVE COPPER WORKS.

These works refine the dressed material from the mine works, but the only portion of the operation shown is the smelting in cupola furnaces of the slags produced in refining the native copper in reverberatory furnaces. These slags are charged into a cupola furnace with limestone and anthracite coal and produce a very impure pig copper. The furnace usually runs 7 to 8 hours, smelting 10 to 14 tons of slag.

The usual proportion of the charge is about 120 pounds of slag, 50 pounds of limestone, and 40 pounds of anthracite coal. After each short run the furnace is dumped and prepared for the next charge. The collection shows:

- (1) Refuse, consisting of slag, cinder, copper, etc., from previous fusions in the cupola. (54330.)
- (2) Slag, average sample; from refining furnaces. (54331.)
- (3) Anthracite coal, used for fuel. (54332.)
- (4) Limestone, used for flux. (54333.)
- (5) Pig copper, product of the smelting. (54335.)
- (6) Slag, crystallized; taken from the casting box above the copper. (54334.)

A single run of the furnace was observed by the collectors, E. B. Kirby, E. M., and E. L. Zukoski, E. M. At 5 p. m. a fire of wood and coke was made up in the furnace to dry it out, and about 800 pounds of coke were used. At 7.30 the next morning regular charging commenced, and at 10.45 six tons of slag had been charged. At 1 p. m. this was all smelted and the copper was tapped. This run of the furnace is represented by five samples of slag:

- (1) Taken at 9.25 a. m. (54336.)
- (2) Taken at 10 a. m. (54337.)
- (3) Taken at 10.30 a. m. (54338.)
- (4) Taken at 11.30 a. m. (54339.)
- (5) Taken at 12.30 a. m. (54340.)

THE SMELTING OF COPPER.

The extraction of copper from its ores may be divided into four processes. In some cases the metal from a given ore will pass through all these stages, while in others some of the stages will be omitted entirely,

and sometimes two or more stages will be more or less combined. Frequently the first operations will be carried on at or near the mines and the product of matte or pig copper shipped away to be refined. This is generally the case if the copper contains silver. These stages are:

First. The preparation of the ore.

Second. The smelting for matte.

Third. The smelting for pig copper.

Fourth. The refining of pig copper for the production of ingot.

Since nearly all copper ores are sulphureted, the most universal preparation is roasting to remove sulphur. In the older works this roasting was generally accomplished by making a pile of the coarsely crushed ore with a small amount of fuel, setting fire to it, and allowing it to burn as long as it would. This operation but imperfectly removed the sulphur, and a portion of each pile had generally to be re-roasted. It was also very long and tedious. Sometimes the coarsely crushed ore is roasted in brick stalls, where the combustion is more under control, more complete, satisfactory, and expeditious. Fine ore, such as results from concentrating operations, is generally roasted in reverberatory furnaces. In all these processes the only object sought is the removal of the sulphur, but ores consisting largely of pyrite are sometimes roasted in specially constructed furnaces, arranged to save the products of combustion and convert the sulphur into sulphuric acid.

The smelting for matte is simply a concentrating operation by fusion. A mixture of the ore is made up with the necessary fluxes, so as to yield a matte consisting of sulphides of copper and iron and a slag containing the earthy impurities of the ore and too little copper to be of any value. This fusion is carried on in either cupola or reverberatory furnaces. This matte is roasted and then smelted again, generally with the addition of rich slags, producing a matte containing more copper and less iron and sulphur and a slag containing sufficient copper to be reworked. This process of roasting and fusing for matte is repeated several times, according to circumstances, until pig copper is produced.

Pig copper contains a small amount of sulphur, together with some other impurities, and has to be refined in a reverberatory furnace to produce ingot copper.

THE VERMONT COPPER MINING COMPANY.

These works represent a condition of affairs not often met with in recent works. They were established for the production of ingot copper from the ores from a single region, and as an adjunct to the mining operations. In more modern practice, the mining company undertakes only the first stages of the smelting or concentrating operations. The refining and production of ingot copper is carried on at independent works, where material can be drawn from a large number of sources. The ores were first roasted in heaps to remove the sulphur. The roasted ore

was then submitted to a series of fusions in reverberatory furnaces for the production of ingot copper. The collection shows :

Ore.

(1) Chalcopyrite, pyrrhotite, blende and quartz, and a mixture of ferruginous silicates, from the Ely Mine, Orange County, Vermont. (17298.)

Intermediate products.

- (1) Roasted ore. (29965.)
- (2) Sulphur, condensed from the roasting heaps. (29969.)
- (3) Sulphide of copper, fused in roasting. (4735.)
- (4) Matte, produced from smelting the roasted ores. (29964.)
- (5) Slag, crystallized, from the fusion for matte. (29966.)
- (6) Roasted matte. (29962.)
- (7) Second matte, produced from first matte, by roasting fusion. (29963.)
- (8) Roasted second matte. (31013.)
- (9) Black copper, produced from roasted second matte, by roasting fusion. "Basin cake." (29967.)
- (10) Pig copper, produced from roasted second matte. (31539.)

Final product.

- (1) Ingot, produced by refining pig or black copper. (31540.)

THE DUCKTOWN COPPER WORKS.

These works were established in the mountains of Tennessee to utilize the ores of the Ducktown mines. Formerly a large amount of copper was produced, but they have now been closed for several years, with no probability of starting up in the near future.

Some oxidized ores were found in the upper portions of the mine, but the large ore bodies were altered sulphides that yet contain a considerable amount of sulphur. The sulphide ores were rudely roasted in heaps, and then subjected to a series of fusions in shaft and reverberatory furnaces. The collection shows :

Ore.

- (1) Oxidized, carbonates of copper, oxides of iron, and quartz. (56370.)
- (2) Sulphide, partially altered pyrite, carbonate of copper, and quartz. (56369.)
- (3) Sulphide, chalcopyrite, pyrite, quartz, and calcite. (56368.)

Intermediate products.

- (1) Roasted ore, roasted in piles of 1,000,000 pounds, two roastings being required, and occupying 3 months. (65277.)
- (2) First matte, obtained in smelting ores in rectangular shaft furnaces 12 feet high. Average composition, 20 per cent. copper, 45 per cent. iron, and 20 per cent. sulphur. (31279.)
- (3) Slag, obtained in ore smelting, contains silica 33 per cent., oxide of iron 54 per cent. (31278.)
- (4) Roasted first matte, the first matte is roasted several times in 60-ton piles, on stone floors, under sheds. (31274.)
- (5) Second matte, obtained by smelting roasted first matte in rectangular shaft furnaces 12 feet high, contains 70 to 75 per cent. copper. (31275.)

- (6) Black copper, obtained with the second matte, contains 90 to 92 per cent. copper. (31276.)
 (7) Blister copper, obtained by smelting second matte in a reverberatory furnace. (31280.)
 (8) Slag, obtained in smelting blister copper. (31277.)

Final products.

- (1) Ingot, from refining blister copper. (31281.)
 (2) Refined copper, cast in a long bar for rod rolling. (31282.)
 (3) Refined copper, cast in a plate for sheet rolling, weighs 220 pounds. (31296.)

THE STE. GENEVIEVE COPPER WORKS.

These works are located at Ste. Genevieve, Ste. Genevieve County, Missouri, and treat the ores of the Cornwall Mine, about 12 miles from the works. The ore from the upper levels of the mine was mostly oxidized, containing a great deal of malachite and oxides of iron, but as these ores have been gradually worked out more and more of the unaltered sulphide ores from the lower levels have been used, necessitating some changes in the operation. The sulphide ores are roasted in large heaps containing about 100 tons each. This is a slow and tedious operation, requiring sometimes 9 months for its completion, and frequently considerable amounts of sulphur remain in the roasted ores.

The ores are first smelted in channel cupola furnaces for the production of matte. A charge in this furnace consists of:

	Pounds.
Raw ore, more or less oxidized.....	125
Roasted sulphide ore	125
Limestone	105
Iron ore	30
Coke	85 to 125

The limestone comes from a quarry near the furnace; the iron ore is a limonite altered from pyrite, and contains some unaltered pyrite. Basic slags from the roaster and refiner are used instead of iron ore when they can be had.

The matte from the cupola smelting is subjected to a roasting fusion in a reverberatory furnace, called the roaster; 7,000 to 10,000 pounds of matte are charged into the furnace and melted, when the slag is skimmed off. The slag is allowed to accumulate again until it covers the bath, when it is again skimmed, and this is repeated until all the blast-furnace slag entangled in the matte has been removed. From three to six of these slags are skimmed off, and are called limestone slags. The bath is then cooled off a little, and subjected to an oxidizing action to remove sulphur and iron, and when this has been carried far enough, the metal, now called pig copper, but really black copper, is tapped from the furnace. The matte yields about 40 per cent. of pig copper in the roaster.

As soon as sufficient pig copper has accumulated to keep the refinery running at least a month the refining furnace, which is a reverberatory, similar to the roaster, is heated up, and the pig copper is charged into it and melted. From 7,000 to 10,000 pounds are charged at a time and about 8 hours are required to melt the charge. When the charge is thoroughly melted all slag that has accumulated is skimmed off. The bath is then exposed to the air to remove the impurities by oxidation, and as soon as sufficient slag has accumulated (generally in about 2 hours), it is skimmed. After this skimming the bath is "flapped," which consists in striking the surface with a rabble, in order to throw the metal in thin sheets into the air, thus exposing a much greater surface to oxidation. During the flapping samples of the bath are taken frequently. The first samples have raised centers, but as the sulphur is removed these become less and less, and finally, as the oxygen begins to be absorbed in excess, the centre sinks, and when it sinks so far as to crack on cooling, "crack set," the flapping is stopped. From 1 to 3 hours are consumed in flapping. Charcoal and wood are then thrown on the bath and the fire urged for 3 or 4 hours with the working door closed.

The bath is now skimmed, sawdust being thrown in to stiffen the slag, and a sample taken. During the first flapping considerable copper chills at the sides of the bath, which melts and runs down into the bath when the door is closed. Should there be sufficient of this copper to prevent the last sample from showing the crack set the bath must be flapped again, but this is rarely necessary.

Up to this point the bath has been subjected to violent oxidation to remove the impurities, the most important of which is sulphur. The total removal of the sulphur can not be accomplished without introducing an excess of oxygen into the metal, which now has to be removed by subjecting the bath to a reducing action. Pine charcoal is thrown over the metal and an oak pole is introduced into the bath through the working door; this causes a violent boiling of the bath, and the excess of oxygen introduced during the flapping is removed. Samples are taken at short intervals, the centre of the sample gradually rises, and the surface becomes covered with fine wrinkles. As soon as it shows a level set, a dark color, fine radiating wrinkles, concentric rings around the edge, and a thick rim without holes, the bath is ready for ladling.

The pole is now removed, the bath skimmed, and some fresh charcoal thrown in to prevent oxidation of the copper. The metal is dipped out in ladles and poured into copper molds. As soon as the surface of the ingot is of the same color all over the mould is turned over and the ingot falls into water. When cold they are removed and packed into barrels. The black copper yields about 80 per cent. of ingot, and ingots weigh from $13\frac{1}{2}$ to 14 pounds.

The collection shows:

Ore.

- (1) Oxidized, malachite in limestone. (55308.)
- (2) Oxidized, malachite containing a little unaltered chalcopryrite and chert. (55309.)
- (3) Sulphide, chalcopryrite in chert. Two characteristic samples. (55311.)
- (4) Sulphide. (55310.)

Flux.

- (1) Iron ore, limonite. (55307.)
- (2) Limestone. (55305.)

Fuel.

- (1) Bituminous coal. (55303.)
- (2) Charcoal, also used as a reducing agent. (55304.)

Intermediate products.

- (1) Matte, from smelting the ores in the cupola. (55291.)
- (2) Cupola slag, black; produced in smelting matte. (55301.)
- (3) Cupola slag, light green; produced in smelting matte. (55302.)
- (4) Cupola slag, crystallized; produced in smelting matte. (55300.)
- (5) First skimming from the roaster. (55281.)
- (6) Second skimming from the roaster. (55282.)
- (7) Third skimming from the roaster. (55283.)
- (8) Fourth skimming from the roaster. (55284.)
- (9) Fifth skimming from the roaster. (55285.)
- (10) Sixth skimming from the roaster. (55286.)
- (11) Seventh skimming from the roaster. (55287.)
- (12) Eighth skimming from the roaster. (55288.)
- (13) Ninth skimming from the roaster. (55289.)
- (14) Tenth skimming from the roaster. (55290.)
- (15) Pig copper, from the roaster. (50990.)
- (16) Furnace bottom charged with metallic copper from the roaster. (55280.)
- (17) First skimming from the refinery furnace. (55292.)
- (18) Second skimming from the refinery furnace. (55293.)
- (19) Third skimming from the refinery furnace. (55294.)
- (20) Fourth skimming from the refinery furnace. (55295.)
- (21) Furnace bottom, charged with metallic copper from the refinery furnace. (55296.)

Final Products

- (1) Ingot copper, small sample. (55298.)
- (2) Ingot copper, small sample, showing coating of red suboxide of copper. (55299.)
- (3) Ingot copper, full size, with its copper mold. (55297.)

Accessories.

- (1) Quartz sandstone, used for making the bottoms and linings of the furnace. (55306.)

THE SCHUYLKILL COPPER WORKS.

These works are located at Phoenixville, Chester County, Pennsylvania and employ the reverberatory furnace process entirely. They treat the ores from various localities, the chief source of supplies being

from various mines in the great bed of magnetite in Berks, Chester, and Lebanon Counties, Pennsylvania.

All of this bed of magnetite carries considerable copper, and at times portions carry sufficient to be worked for that metal. The ores consist of magnetite and sulphides of copper, together with decomposition products of the latter, including silicates and carbonates.

The ores are represented by eight specimens.

(1) Silicate and carbonate of copper, on magnetite. Jones Mine, Berks County, Pennsylvania. (5163.)

(2) Chalcopyrite, silicate and carbonate of copper, on magnetite. Jones Mine, Berks County, Pennsylvania. (5154.)

(3) Chalcopyrite and malachite. Jones Mine, Berks County, Pennsylvania. (5175.)

(4) Chalcopyrite, in rough crystals, and magnetite. Jones Mine, Berks County, Pennsylvania. (5164.)

(5) Chalcopyrite, carbonate of copper, and magnetite. Jones Mine, Berks County, Pennsylvania. (5165.)

(6) Chalcopyrite. French Creek Mine, Chester County, Pennsylvania. (5167.)

(7) Chalcopyrite, pyrite, crystallized, and magnetite, with a slight coat of carbonate of copper. French Creek Mine, Chester County, Pennsylvania. (5161.)

(8) Carbonate of copper, impure. Cornwall Iron Mine, Lebanon County, Pennsylvania. (11679.)

The process at these works is divided into five distinct operations.

First operation.—The ores are subjected to a roasting fusion, whereby the copper and a considerable amount of the iron, in the form of sulphides, are concentrated into matte. (31298.)

The earthy impurities of the ores form a slag sufficiently free from copper to be thrown away. (31299.)

Second operation.—The first matte is subjected to a roasting fusion, whereby a second matte, called "blue metal," containing more copper, and less iron and sulphur, is obtained. (31301.)

The slag obtained in this operation contains a considerable percentage of copper, and is used as a flux in the first operation. (31302.)

Third operation.—The blue metal is subjected to a roasting fusion, whereby a third matte, called "white metal," containing more copper, and less iron and sulphur, than blue metal, is obtained. (31305.)

The slag contains a large percentage of copper, and is used as a flux in the second operation. (31303.)

This operation is further illustrated by two samples of white metal, extra, showing filaments of metallic copper, commonly called "Nigger Wool." (31306 and 31307.)

Fourth operation.—The white metal is subjected to a roasting fusion, whereby blister copper is obtained. Blister copper contains only a small amount of impurities. (31309.)

The slag contains a very large percentage of copper, and is used as a flux in the third operation. (31310.)

Fifth operation.—The blister copper is first melted and subjected to the oxidizing action of the air, in order to remove the impurities as far as possible. This operation introduces a large excess of oxygen into

the metal which must be removed. A stick of green wood is plunged into the bath of copper, charcoal is thrown on its surface, and the air excluded from the furnace as much as possible. The final product of this treatment is ingot copper, which is ready for use. (31311.)

The slag obtained in this operation is essentially oxide of copper, and is utilized in the fourth operation. (31312.)

In the course of this process copper frequently works its way through the bottom of the furnace, and three characteristic samples of this are shown. (31313, 31314, and 31315.)

THE ORFORD COPPER AND SULPHUR COMPANY.

These works are located at Bergenport, New Jersey, and treat mainly the sulphide ores of the Crown Mine, Capelton, Province Quebec, Canada.

The sulphur of the ores is first utilized for the manufacture of sulphuric acid and afterwards the copper is extracted by a combined treatment in the blast and reverberatory furnaces.

(1) Sulphide ore, chalcopryite, pyrite, and quartz, containing about 40 per cent. sulphur and 4 per cent. copper. (40220.)

(2) Roasted or burnt ore, the residue remaining after the sulphur has been burnt off for the manufacture of sulphuric acid. (49347.)

(3) First matte, obtained in smelting the roasted ore, contains about 30 per cent. copper. (49348.)

(4) Slag, produced in smelting for first matte. (49349.)

(5) Ground and roasted matte, containing about 36 per cent. copper. (49350.)

(6) White metal, obtained by smelting roasted matte. (49351.)

(7) Blister copper, obtained by smelting white metal. (49352.)

(8) Ingot copper, obtained by refining blister copper. (49353.)

THE BUTTE COPPER DISTRICT.

Within a very small area near the city of Butte, Silver Bow County, Montana, occurs a group of very remarkable copper mines. The copper occurs in veins, frequently of great width, in coarse-grained granite. The surface of these veins consisted of quartzose material, with oxides of iron, copper minerals being rare. They, however, carried considerable silver, and most of the large copper mines were originally opened as silver mines. After reaching the water level, which varies from 50 to 150 feet from the surface, the character of the vein changes entirely, and consists of quartz carrying various sulphides of copper and iron, alone and mixed. These sulphides vary from a nearly pure chalcocite, through bornite, to chalcopryite, although but small amounts of the latter have been mined, and are frequently associated with pure sulphide of iron, pyrite.

In some of the mines the principal copper mineral is chalcocite, while in others it is bornite, and this distinction is quite marked. All the ores carry more or less silver, and, especially in the chalcocite mines, free silver is found in beautiful sheets on the sulphide of copper. The width of the veins varies, and it is not unusual to find 30 feet or more

of solid ore, most of it, however, being second class or concentrating ore. Within the vein are frequently found chutes of rich ore, irregularly distributed. Large bodies of nearly pure chalcocite were found in some of the mines, especially the Anaconda.

The ores of the region may be divided into three classes. First, shipping ore, consisting of high grade chalcocite ore, carrying 50 per cent. of copper, which is shipped away for smelting. Second, smelting ore carrying about 30 per cent. of copper, which is smelted on the spot. Third, concentrating ore, carrying from 10 to 20 per cent. of copper, which is first roughly concentrated and then smelted. Owing to the cost of labor and the lack of local consumption, the smelting is confined to a single operation for the production of a high grade matte.

MONTANA SMELTER.

These works treat the ore from several of the mines, but especially the Colusa, which carries most of its copper in the form of chalcocite. Besides chalcocite the ore contains considerable pyrite and a little bornite. Solid lumps of the rich sulphide generally contain native silver in very thin plates. The rich ores are shipped away directly, the second quality are treated for the production of matte in a reverberatory furnace, while still poorer ores are concentrated by jigging, and then treated for matte.

Ore.

- (1) Chalcocite, containing a little pyrite and showing small flakes of free silver. Shipping ore. (55639.)
- (2) Chalcocite, bornite, pyrite, and quartz. Concentrating ore. (55629.)
- (3) Crushed ore. (55628.)
- (4) Coarse concentrates, containing a great deal of chalcocite and being very rich in copper. (55626.)
- (5) Medium concentrates, containing some pyrite and quartz. (55625.)
- (6) Fine concentrates, containing considerable pyrite and quartz. (55624.)
- (7) Tailings, consisting largely of quartz. (55623.)

Flux.

- (1) Limestone. (55636.)
- (2) Iron ore. (55634.)

Fuel.

- (1) Bituminous coal, from Bozeman, Montana. (55633.)
- (2) Bituminous coal, from Pleasant Valley, Utah. (55637.)

Final products.

- (1) Matte, containing 65 per cent. of copper and 55 to 60 ounces of silver per ton. (55616.)
- (2) Slag, produced in smelting matte. (55618.)

Accessories.

- (1) Quartz, used for making furnace bottoms. (55635.)
- (2) Blister copper, from old blast-furnace smelting. (55633.)
- (3) Slag, from old blast furnace smelting. (55622.)

PARROTT SMELTER.

These works treat the ore from the Parrott Mine, which carries its copper mostly in the form of bornite. The ores are divided into first quality, which are smelted directly in reverberatory furnaces, and second quality or concentrating ore.

Ore.

- (1) Bornite and pyrite, in quartz. First quality. (55586.)
- (2) Bornite and pyrite, in quartz. Concentrating ore. (55585.)
- (3) Bornite and pyrite, with a little quartz; a mixture of several sizes of concentrates. (55583.)
- (4) Tailings, consisting of quartz with a small amount of sulphides. (55584.)

Intermediate products.

- (1) Lump ore, roasted in stalls. (55581.)
- (2) Concentrates, roasted in a reverberatory furnace. (55582.)
- (3) Concentrates, roasted and pressed into a brick. (55590.)

Final products.

- (1) Matte, from reverberatory furnace. (55579.)
- (2) Slag, produced with matte. (55580.)

Accessories.

- (1) Quartz, used for making bottoms of furnaces. (55589.)

BELL SMELTER.

These works treat the ores of the Bell Mine in shaft furnaces. The ores are divided into first-class and concentrating ores. The first-class ores are roasted in heaps, and the concentrated ores are roasted in reverberatory furnaces.

Ores.

- (1) Bornite, pyrite, and quartz. First-class ore. (55611.)
- (2) Bornite and pyrite; a mixture of several grades of concentrates. (55613.)

Intermediate products.

- (1) Lump ore, roasted in heaps. (55610.)
- (2) Concentrates, roasted in reverberatory furnaces. (55612.)

Flux.

- (1) Limestone. (55615.)
- (2) Iron ore. (55614.)

Final products.

- (1) Matte, from smelting the roasted ores. (55604.)
- (2) Matte, showing filaments of metallic copper. (55606.)
- (3) Slag, average sample. (55607.)
- (4) Slag, crystallized in thin blades. (55608.)
- (5) Slag, in thick heavy crystals. (55609.)

ARIZONA COPPER DISTRICT.

The copper mines of Arizona are remarkable as having produced large quantities of oxidized ores. These ores occur for the most part in large deposits at and near the surface and are extracted by the simplest quarrying operations. They contain 10 to 15 per cent. of copper, and, owing to their oxidized condition, a single fusion in a water-jacketed cupola furnace produces pig copper carrying from 97 to 98 per cent. of the metal. In many instances no flux is required, since a mixture of the ore can be made that will be self-fluxing. In some cases, however, limestone is used. It will thus be seen that both the mining and smelting are exceedingly simple and inexpensive. Fuel, however, is very dear, having cost over \$50 per ton at some of the works.

This region is illustrated by a collection from the Copper Queen mine, Bisbee, Cochise County, taken by Mr. B. Williams, which shows a great variety of the ores. The collection begins with a sample of free copper, which has evidently been produced as a secondary product from the other copper minerals. It then follows on through various stages of oxidation to malachite.

COPPER QUEEN MINE AND SMELTER.

Ore.

- (1) Free copper, crystallized on siliceous limonite. (56043.)

Oxidized ore.

- (1) Cuprite, crystallized on limonite. The crystals are well-developed octahedrons with cubic faces, mostly in separate individuals. (56050.)
(2) Cuprite, in crystalline coating and layers, on limonite. (56047.)
(3) Azurite, crystallized. (56052.)
(4) Azurite, crystallized, malachite, limonite; the azurite occurs in the interior of a cavity surrounded by the malachite and limonite. (56051.)
(5) Azurite, malachite, limonite; the azurite occurs in separate crystalline aggregates on fibrous globular malachite. (56056.)
(6) Malachite, azurite, oxide of manganese. A mixture of malachite and azurite, coated on the exposed surface with oxide of manganese. (56057.)
(7) Malachite, a fibrous globular coating on the interior of a cavity. (56060.)
(8) Malachite, a fibrous globular malachite in a cellular mass and showing the interior of one large cavity. (56059.)
(9) Malachite, with a little azurite, cellular, massive; showing a small elongated cavity with stalactites. (56058.)
(10) Average sample, from open surface cut. (56069.)
(11) Average sample, from lower working. (56070.)
(12) Average sample, representing a 3-days run of the furnaces; the charge being open cut ore 30 pounds, lower workings ore 245 pounds, limestone 25 pounds. (56068.)

Slag.

- (1) From the blast furnace. (56071.)

A sample of the pig copper may be seen in the collection from the Ansonia works.

The pig copper of the region is generally free from injurious impurities, especially arsenic, and has a high reputation at the refineries. It is all shipped away to be refined, much of it being treated at works in the East.

The refining process is well illustrated by a collection from the Ansonia Brass and Copper Works, Ansonia, New Haven County, Connecticut, taken by Mr. Wm. Powe.

Ansonia Brass and Copper Works.—The process of refining is essentially the same as that described in refining the pig copper at Ste. Genevieve.

- (1) Pig copper, from Arizona. (54344.)
- (2) Roller scale, produced in heating and rolling copper and used in the refining process to assist in the oxidation of the impurities of the copper. (54345.)
- (3) Copper, taken from the bath after the first skimming of the slag, when the charge becomes thoroughly melted. (54347.)
- (4) Slag, drawn from the furnace when the charge is first melted. (54351.)
- (5) Copper, taken from the bath after working, during which the sulphur and other impurities have been removed by rapid oxidation; time of working 9 hours. (54348.)
- (6) Slag, drawn from the furnace during the working period. (54352.)
- (7) Copper, taken from the bath after rabbling to fine copper. Rabbling removes the small amount of impurities left in the copper after working, and requires from 1 to 2 hours. (54349.)
- (8) Slag, drawn from the furnace at the close of the oxidizing period. (54353.)
- (9) Copper, taken from the bath after poling to tough copper; time of poling about 2 hours. (54350.)
- (10) Slag, drawn from the furnace just after beginning to pole. (54354.)
- (11) Siliceous sand, used to repair the bottom of the refining furnace. (54346.)
- (12) Pole (buttonwood poplar), used to refine the copper bath. (55403.)
- (13) Clay, used for lining ladles. Woodbridge, Middlesex County, New Jersey. (55399.)
- (14) Bituminous coal, used in gas producers. (55402.)
- (15) Pig copper, obtained by smelting refinery slags and other refuse in a cupola furnace. (54355.)
- (16) Slag, clean slag, obtained in smelting refinery slags, etc., in the cupola. Thrown away. (54398.)
- (17) Anthracite coal, used for fuel in the cupola. (55400.)
- (18) Oyster shells, used for flux in the cupola. (55401.)
- (19) Furnace bottom, taken from the cupola and containing metallic copper. (54356.)

WET PROCESS OF COPPER EXTRACTION.

Many ores contain copper in a form that can not be readily concentrated by mechanical means and are yet too low in copper to be treated directly by any of the fusion processes. To utilize such ores several wet processes have been devised.

THE HUNT AND DOUGLASS COPPER PROCESS.

This process consists of treating the oxides of copper with a solution of proto-chloride of iron and salt. By this operation the copper is converted into subchloride by the proto-chloride of iron, and is dissolved by the salt, the proto-chloride of iron being oxidized to the sesqui-

chloride. The solution containing copper is then left for some time in contact with scrap wrought iron, which reduces the copper to the metallic state, while the sesqui-chloride of iron is reduced to the proto-chloride and is ready to be used over again.

In the cases of oxides and carbonates of copper, and some silicates, like chryscolla, the process can be applied directly, but some of the silicates have to undergo a previous treatment before the process can be applied. Sulphide ores of copper are crushed and roasted to convert the copper into oxide and sulphate before treatment. This process is applicable to all ores of copper, except such as contain large amounts of the carbonates of lime, magnesite, or zinc, and is especially applicable to silver-bearing copper ores.

The process was formerly carried on by the Chemical Copper Company, Phoenixville, Chester County, Pennsylvania, and is illustrated by the following specimens:

Ore.

(1) Chalcopyrite, with some silicates and carbonates of copper, and magnetite; sulphide ore. This ore comes from the copper-bearing portion of a large deposit of magnetite which is mined for iron smelting. It contains 3 to 4 per cent. of copper, and 30 to 50 per cent. of iron. Jones Mine, Berks County, Pennsylvania. (5157.)

(2) Clay, containing copper, also traces of zinc and nickel; silicate ore. This material forms great beds underlying the magnetite ores, and contains about 4 per cent. of copper. Jones Mine, Berks County, Pennsylvania. (11673.)

Intermediate products.

(1) Sulphide ore, crushed to pass a screen of fifteen holes to the linear inch, ready for roasting. Contains about 3 per cent. of copper. (5152.)

(2) Roasted sulphide ore, after passing through a three-hearth reverberatory furnace. It contains 1.45 per cent. of copper in the form of oxide; 1.25 per cent. in the form of sulphate, and 0.30 per cent. in the form of unoxidized sulphide. (5148.)

(3) Residue, left after treating the roasted ore with solution of proto-chloride of iron and salt and washing. It still contains about 0.40 per cent. of copper, mostly as sulphide. (5153.)

(4) Concentrates, obtained by washing the residues. Contain about 67 per cent. of iron, and are used for fettling puddle furnaces. (5150.)

(5) Silicate ore, average sample as prepared for preliminary treatment. Contains 4 per cent. of copper. (5149.)

(6) Silicate ore, after preliminary treatment. The raw ore is dried, and then charges of 15,000 pounds are heated to redness in a close muffle with a small amount of pulverized coal. By this operation the oxide of copper of the silicate is reduced to the metallic state. The charge is withdrawn from the muffle and cooled with free access of air, by which the copper is again oxidized and thus prepared for solution. (5151.)

(7) Residues, after treating the prepared silicate ore with a hot solution of proto-chloride of iron and salt; still retains 0.50 per cent. of copper. (5146.)

Final products.

(1) Cement copper, crystallized metallic copper; separated from the solution by passing over wrought scrap iron. Average sample. (5147.)

(2) Cement copper, finely crystallized. (30931.)

(3) Cement copper, compressed in an ordinary brick machine preparatory to melting into ingots. (29945.)

(4) Cement copper, compressed by hydraulic pressure preparatory to melting into ingots. (29946.)

(5) Ingot, obtained from the pressed cement copper by a single fusion in a reverberatory furnace. (29947.)

APPLICATION OF COPPER.

A single illustration of the application of copper in the rolling of rods and plates and the coating of the latter with other metals, as practiced at the works of the Ansonia Brass and Copper Company, Ansonia, New Haven County, Connecticut, is illustrated by a collection taken by Mr. L. Powe and Mr. Henry Cooper, 1884.

Rod rolling.

(1) Rolled hot, shows scales of oxide formed during the heating and rolling. (51183.)

(2) Rolled hot, has been pickled in dilute sulphuric acid to remove the scale of oxide of copper formed during the heating and rolling. (51184.)

(3) Rolled hot, pickled and then finished by cold rolling. (54362.)

(4) Rolled hot, pickled, rerolled hot and, after cooling, drenched with dilute ammonia, heated to a dull red and quenched in cold water to remove the scale. (51185.)

Plate rolling.

(1) Rolled hot, shows scale of oxide formed during the heating and rolling. (54359.)

(2) Rolled hot, has been pickled in dilute sulphuric acid to remove the scale of oxide of copper formed during the heating and rolling. (54357.)

(3) Rolled hot and pickled and then finished by cold rolling. (54358.)

(4) Rolled hot, pickled, rerolled hot and, after cooling, drenched with dilute ammonia, heated to a dull red and quenched in cold water to remove the scale. (54360.)

(5) Scale, from the quenching of plate. (54361.)

Sheet copper.

(1) Hard-rolled. Hard rolling is passing the plate a few times through the rolls to harden and temper it. (54367.)

(2) Hard-rolled, showing spring temper. (54369.)

(3) Cold-rolled, soft or annealed. (54370.)

(4) Hard-rolled, tinned. (54364.)

(5) Cold-rolled, tinned. (54366.)

(6) Patent planished. (54368.)

(7) Tinned and patent planished. (54365.)

(8) Patent nickel plated. (54363.)

(9) Patent nickel plated and tinned. (54371.)

(10) Silver plated, to be used in gold amalgamating mills; contains 1 ounce of silver per square foot. (54372.)

I R O N .

IRON MINERALS.

MAGNETITE. (MAGNETIC IRON ORE, LOADSTONE.)

Composition: $\text{Fe}_2\text{O}_3 + \text{FeO}$. Protosesquioxide of iron, containing iron 72.4 per cent. and oxygen 27.6 per cent.

It crystallizes in the isometric system, especially in octahedrons and dodecahedrons. It commonly occurs in the crystalline granular form, with grains of various sizes, or massive. It varies in hardness from 5.5 to 6.5, and in specific gravity from 4.9 to 5.2. It has a full metallic luster, and iron-black color. It is always magnetic and sometimes shows polarity.

Magnetite is a very valuable source of iron. Sometimes it occurs in masses of great purity and furnishes iron of the highest quality. It frequently contains the various sulphides of iron, the phosphate of lime, apatite, and titanite acid, and any one or several of these may be present in sufficient amount to prevent its being utilized. It generally occurs in the older crystalline rocks. To illustrate the occurrence of magnetite five specimens are shown:

(1) Crystallized, small octahedrons on massive. O'Neil Mine, Orange County, New York. (17642.)

(2) Crystallized, large octahedrons on massive. Great Western Mine, Iron Springs, Iron County, Utah. (43648.)

(3) Crystalline, granular. Crown Point Mine, Crown Point, Essex County, New York. (65320.)

(4) Massive, loadstone. Arkansas. (31965.)

(5) Magnetic sand, from washing alluvial deposit. December 27, 1880. White River, Pittsfield, Rutland County, Vermont. (65330.)

HEMATITE. (RED HEMATITE, SPECULAR IRON, MICACEOUS IRON, IRON GLANCE.)

Composition: Fe_2O_3 . Sesquioxide of iron, containing iron 70 per cent. and oxygen 30 per cent.

Crystallizes in the rhombohedral system, crystals being generally rhombohedral or tabular, with rhombohedral faces. It occurs granular, lamellar, massive, and earthy.

It varies in hardness from 5.5 to 6.5 and in specific gravity from 4.5 to 5.3; it is dark steel-gray to red in color and bright metallic to earthy in luster; is generally opaque, but occasionally, in thin crystals, transmits a blood-red light. The powdered mineral is always bright red in color.

Hematite occurs in a variety of forms in rocks of all ages and is a very valuable source of iron. As an ore it has received a large variety of names, depending for the most part upon the physical condition of

the mineral. To illustrate the occurrence of hematite five specimens are shown :

- (1) Tabular crystals, on massive. Iron Ridge, Crawford County, Missouri. (40729.)
- (2) Specular. Lake Superior Mine, Ishpeming, Marquette County, Michigan. (5358.)
- (3) Micaceous specular. Negaunee, Marquette County, Michigan. (5335.)
- (4) Massive. Athens, McMinn County, Tennessee. (20068.)
- (5) Fossiliferous. Ferguson Valley, Lewiston, Pennsylvania. (5183.)

LIMONITE. (BROWN HEMATITE, BOG IRON ORE.)

Composition: $\text{Fe}_2\text{O}_3 + \text{Fe}_2\text{H}_6\text{O}_6$. Hydrated sesquioxide of iron, containing sesquioxide of iron 85.6 per cent. (iron, 59.9 per cent.), and water 14.4 per cent.

It does not crystallize, but is generally found in various imitative shapes with fibrous structure, frequently coating the interior of cavities. It also occurs massive. It varies in hardness from 5 to 5.5, and in specific gravity from 3.6 to 4. The luster on the original surface is often bright metallic, and dark in color, while on a fresh fracture the luster is generally silky, and the color brown; occasionally it occurs earthy. The powdered material is always yellowish brown.

Limonite is the most widely distributed ore of iron, and as the metal is very easily reduced from it, has been utilized in remote and inaccessible regions for long ages. The purer varieties yield a metal of great strength, well suited for making castings, and especially car wheels. To illustrate the occurrence of limonite two specimens are shown :

- (1) Botryoidal and stalactitic, fibrous coating on the interior of cavity. Chatfield Mine, Salisbury, Litchfield County, Connecticut. (17302.)
- (2) Massive. Mine No. 1, Lowmoor, Alleghany County, Virginia. (5301.)

TURGITE.

Composition: $5 \text{Fe}_2\text{O}_3 + \text{Fe}_2\text{H}_6\text{O}_6$. Hydrated sesquioxide of iron, containing sesquioxide of iron 94.7 per cent. (iron, 66.3 per cent.), and water 5.3 per cent.

Does not crystallize, but resembles limonite, with which it is generally associated in its occurrences and physical properties, but from which it can most readily be distinguished by its powder being red.

To illustrate the occurrence of turgite two specimens are shown :

- (1) Coating the interior of a cavity on limonite. Porter Ore Bed, Salisbury, Litchfield County, Connecticut. (11694.)
- (2) Powdered sample, showing characteristic red color. Porter Ore Bed, Salisbury, Litchfield County, Connecticut. (65321.)

SIDERITE. (SPATHIC IRON.)

Composition: FeCO_3 . Carbonate of protoxide of iron, containing protoxide of iron 62.1 per cent. (iron, 49.0 per cent.), and carbonic acid 37.9 per cent. Generally a part of the iron is replaced by manganese.

It crystallizes in the rhombohedral system, showing mostly planes of rhombohedrons; crystals are usually curved. Its most common occurrence is in crystalline masses, showing the characteristic rhombohedral cleavage with curved faces. It frequently occurs granular. It varies in hardness from 3.5 to 4.5, and in specific gravity from 3.7 to 3.9, is generally gray to brown in color, and has a vitreous luster.

Siderite is the chief constituent of several varieties of iron ores, which are generally more or less impure. To illustrate the occurrence of siderite two specimens are shown:

- (1) Crystalline, massive, showing characteristic cleavage. Shepaug Iron Company's mine, Roxbury, Litchfield County, Connecticut. (17966.)
- (2) Massive, fine granular. Muirkirk, Prince George County, Maryland. (65322.)

PYRITE. (MUNDIC.)

Composition: FeS_2 . Bisulphide of iron, containing iron 46.7 per cent., and sulphur 53.3 per cent. Occasionally other metals replace some of the iron.

It crystallizes in the isometric system, forming very beautiful crystals. The most common form is the cube, while the pyritohedron and related forms are quite common, and combinations of these two forms are frequent. It also occurs in imitative forms with crystalline structure. Much of it occurs massive.

It varies in hardness from 6 to 6.5, and in specific gravity from 4.83 to 5.2. It has a full metallic luster, and pale brass-yellow color. On being struck with a hard substance, like steel, it throws off sparks, whence the name.

Pyrite is never used directly as a source of iron, and its presence in any large amounts in iron ores is a great injury, as it causes the metal to be weak at high temperature or "red short." Small amounts of it are, however, common in nearly all iron ores, and considerable amounts can be removed by a suitable roasting operation.

Considerable amounts of it are used in the manufacture of sulphuric acid, and after the small amount of copper frequently present has been extracted, the remaining, nearly pure oxide of iron, known as "blue-billy," is sometimes used in the puddling process of making wrought iron. To illustrate the occurrence of pyrite the following specimen is shown here. Others will be found in the sulphur collection.

- (1) Crystallized, on magnetite. Annie Mine, Lake County, Colorado. (41885.)

IRON ORES.

The ores of iron are classified in several different ways, the most important being according to the chief mineral they contain, as magnetite, hematite, limonite, and carbonate ores. With the exception of magnetite, each one of these varieties is frequently subdivided according to some peculiar physical character; thus under hematite we have specular, micaceous, fossil; under limonite we have bog, needle, pipe; under siderite we have clay-ironstone, and blackband ore. Many

other varieties are recognized locally. Hematite and limonite are frequently indiscriminately called hematite; they are also frequently distinguished as red and brown hematites. Occasionally, also, a single physical name will include two or more chemical varieties; thus, honey-comb ore may be either hematite or limonite, while kidney ore may be either hematite, limonite, or siderite.

Iron ores are frequently classified according to the character of the pig metal that they will produce, and this classification depends mainly upon the presence or absence of impurities; thus, a steel ore must be low in phosphorus, while a cold short ore will be high in phosphorus, a red short ore will be high in sulphur, and a neutral ore is one containing moderate amounts of both sulphur and phosphorus, but in such proportions that they more or less neutralize each other.

THE TENTH CENSUS IRON-ORE COLLECTION.

Under the direct supervision of Prof. R. Pumpelly, the Tenth Census made a very elaborate collection of the iron ores of the country. The design of this collection was to take representative samples of each variety of ore occurring at every mine that was worked during the census year. Besides these, a complete sample of the ore as mined was taken and submitted to a chemical examination. To these were added illustrations of the associated rocks and minerals. This whole collection embraced nearly four thousand specimens, and a suitable selection of these has been placed on exhibition. The exhibition series is arranged upon a geographical basis. Several illustrations of manganese ore are included in the collection.

MAINE.

PISCATAQUIS COUNTY.

Ten specimens represent the ore mined by the Katahdin Iron Company, taken October 15, 1880.

- (1) Limonite, commonly called bog o.c. (42160.)
- (2) Limonite. (41349.)
- (3) Limonite. (42157.)
- (4) Limonite. (42158.)
- (5) Limonite, raw ore. (41350.)
- (6) Roasted ore. (42156.)
- (7) Pyrite, showing alteration to limonite, and representing the original source of the ore. (42159.)
- (8) Trap rock, occurring in connection with the ore, containing a large percentage of sulphide of iron, considerably decomposed. (41351.)
- (9) Trap rock, containing pyrrhotite; probably the unaltered form of 41351. (43662.)
- (10) Trap rock, probably the non-pyritiferous portion of 41351. (42098.)

VERMONT.

ADDISON COUNTY.

- (1) Limonite, surface ore. Monkton Mine, Monkton, October 23, 1880. (42099.)

RUTLAND COUNTY.

- (1) Granitic rock, containing magnetite. Bethel Iron Company's Mine, Pittsfield. November 1, 1880. (41329.)
- (2) Magnetite sand, separated from 41329 by crushing and washing. Bethel Iron Company's mine, Pittsfield. November 1, 1880. (42100.)
- (3) Limonite. Brandon Mine, Brandon. October 25, 1880. (41331.)
- (4) Limonite. Forrest Dale Mine. October 25, 1880. (41326.)

WINDSOR COUNTY.

- (1) Siderite. Tyson Furnace, Plymouth. October 30, 1880. (43607.)

MASSACHUSETTS.

BERKSHIRE COUNTY.

- (1) Limonite. Chauncey Leet Mine, West Stockbridge. September 17, 1880. (42283.)
- (2) Limonite. Goodrich Mine, West Stockbridge. September 17, 1880. (42284.)
- (3) Impure limonite. Cone Mine, Richmond. (42285.)
- (4) Limonite. Cheever Mine, Richmond. September 18, 1880. (41348.)
- (5) Limonite. Bacon Mine, Richmond. September 18, 1880. (42286.)

RHODE ISLAND.

- (1) Magnetite, natural magnetic sand. Block Island. January 18, 1881. (42097.)

PROVIDENCE COUNTY.

- (1) Magnetite, containing titanitic acid. Cumberland Hill, Cumberland. December 4, 1880. (42095.)
- (2) Magnetite, containing titanitic acid and quartz. Cumberland Hill, Cumberland. December 4, 1880. (42096.)

CONNECTICUT.

LITCHFIELD COUNTY.

Twenty-four specimens represent the celebrated Salisbury district in Litchfield County, the first fifteen of which are from the Ore Hill Mine, taken September 6, 1880.

- | | |
|--|---|
| (1) Limonite. (41344.) | (16) Limonite. Chatfield Mine. (41341.) |
| (2) Limonite. (43694.) | (17) Limonite. Chatfield Mine. (41338.) |
| (3) Limonite. (41340.) | (18) Limonite. Chatfield Mine. (42287.) |
| (4) Limonite. (41342.) | (19) Pyrolusite, and limonite. Davis Mine. (42288.) |
| (5) Limonite. (43599.) | (20) Limonite. Davis Mine. (41339.) |
| (6) Limonite. (43598.) | (21) Limonite. Scoville Mine. (41343.) |
| (7) Limonite. (43693.) | (22) Limonite. Scoville Mine. (42289.) |
| (8) Limonite. (43600.) | (23) Limonite. Kent Mine. (41337.) |
| (9) Limonite. (43601.) | (24) Limonite, a conglomerate of dark colored limonite cemented by lighter colored, with small crystals of quartz in the crevices; not used as an ore, and occurs in bunches through the deposit. Kent Mine. (41336.) |
| (10) Limonite. (43689.) | |
| (11) Limonite. (43695.) | |
| (12) Decomposed slate from above the ore. (43688.) | |
| (13) Slate from under the ore. (43692.) | |
| (14) Slate from under the ore. (43691.) | |
| (15) Slate from under the ore. (43690.) | |

NEW YORK.

CLINTON COUNTY.

Fourteen specimens represent the Chateaugay Mine, at Dannemora, taken June 8, 1881.

- (1) Magnetite, containing pyrite, and feldspar. (40846.)
- (2) Magnetite, containing quartz, and feldspar. (40850.)
- (3) Magnetite, containing quartz, and feldspar. (43720.)
- (4) Impure magnetite, containing much pyrite. (65379.)
- (5) Magnetite, quartz, feldspar; furnace ore. (43720.)
- (6) Magnetite, and quartz; concentrating ore. (43719.)
- (7) Magnetite, and dark green silicates of iron; concentrating ore. (65378.)
- (8) Magnetite, scattered through a large amount of gangue. (40851.)
- (9) Gangue, fine grained, containing considerable magnetite. (43718.)
- (10) Gangue, containing some magnetite. (65380.)
- (11) Gangue, coarse grained, containing a little magnetite. (65381.)
- (12) Wall rock, gray. "Williams Pit." (43721.)
- (13) Wall rock, pink. "Williams Pit." (65383.)
- (14) Gangue, coarse crystals of feldspar, pyroxene, and quartz, containing a little magnetite. "Williams Pit." (43722.)

Nine specimens represent the Arnold Hill Mine, Au Sable, taken June 4, 1881.

- | | |
|---|------------------------------------|
| (1) Magnetite, containing a little apatite. (40839.) | (5) Martite. (40842.) |
| (2) Magnetite. (40838.) | (6) Magnetite and quartz. (40833.) |
| (3) Magnetite and quartz. (40827.) | (7) Magnetite and quartz. (40837.) |
| (4) Magnetite and quartz. (40831.) | (8) Rock, from dike. (40835.) |
| (1) Magnetite, quartz, and feldspar. Palmer Hill Mine, Blackbrook. (40840.) | (9) Rock, from wall. (40816.) |

ESSEX COUNTY.

Twenty-seven specimens represent the Mount Moriah District, the first fifteen being from the Cheever Mine, Moriah; taken May 20, 1881.

- (1) Magnetite, containing apatite. (43760.)
- (2) Magnetite, apatite, and quartz. (41960.)
- (3) Magnetite, containing apatite and calcite. (43762.)
- (4) Magnetite. (43759.)
- (5) Magnetite, pyroxene, apatite, and feldspar. (43756.)
- (6) Magnetite. (40897.)
- (7) Magnetite. (40899.)
- (8) Magnetite. (40907.)
- (9) Hanging wall, containing much magnetite. (43765.)
- (10) Granitic wall rock, containing considerable magnetite. (43757.)
- (11) Granitic wall rock, containing some magnetite. (43763.)
- (12) Granitic wall rock, containing much magnetite. (43761.)
- (13) Slickensides, from face of fault. (43764.)
- (14) Slate, from face of fault. (43758.)
- (15) Slate, from face of fault. (43675.)
- (16) Magnetite and quartz. New Bed Mine, May 27, 1881. (40904.)
- (17) Magnetite. Mineville Mine, "Old Bed". July 7, 1881. (41965.)
- (18) Magnetite. Mineville Mine, "Welsh Shaft". July 7, 1881. (40893.)
- (19) Magnetite, apatite, decomposed feldspar. Mineville Mine, "Welsh Shaft". July 1, 1881. (40896.)

- (20) Magnetite and apatite. Mineville Mine, "Noland's Shaft". July 6, 1881. (40895.)
 (21) Magnetite and apatite. Mineville Mine, "Potts Shaft". July 7, 1881. 41964.)
 (22) Magnetite, cleavable, decomposed silicates; surface ore. Mineville Mine No. 21. May 27, 1881. (40901.)
 (23) Magnetite, cleavable, decomposed silicates; surface ore. Mineville Mine No. 21. May 27, 1881. (40900.)
 (24) Magnetite, shows cleavage. Mineville Mine No. 21. July 6, 1881. (40902.)
 (25) Magnetite, containing apatite. Mineville Mine, Miller Pit. July 6, 1881. (40905.)
 (26) Magnetite, apatite, and quartz. Mineville Mine, "Teft Shaft." July 7, 1881. (40898.)
 (27) Magnetite, containing apatite. Mineville Mine, "Teft Shaft." July 7, 1881. (40905.)
 (28) Magnetite and quartz. Hammonville Mine, Crown Point. June 29, 1881. (40892.)
 (29) Magnetite and quartz. Hammonville Mine No. 8, Crown Point. June 29, 1881. (40894.)
 (30) Magnetite and quartz. Hammonville Mine, Crown Point. June 29, 1881. (40891.)

WASHINGTON COUNTY.

- (1) Magnetite, containing quartz. Potter Mine, Fort Ann. May 5, 1881. (40952.)
 (2) Magnetite and quartz. Potter Mine, Fort Ann, May 5, 1881. (40950.)
 (3) Magnetite, containing micaceous silicates. Mount Hope Mine, Fort Ann. May 7, 1881. (40951.)

ST. LAWRENCE COUNTY.

Four specimens represent the Jayville Mine, Fine; taken June 22, 1881:

- | | |
|-----------------------------------|-------------------------|
| (1) Magnetite, pyroxene. (40857.) | (3) Magnetite. (40855.) |
| (2) Magnetite, pyrite. (40872.) | (4) Magnetite. (40860.) |

Five specimens represent the Gouverneur district; taken June 21, 1881:

- (1) Hematite, quartz. Caledonia Mine, Fox Pit. (40853.)
 (2) Hematite. Caledonia Mine, Dillmann's Pit. (40871.)
 (3) Hematite. Caledonia Mine, Dillmann's Pit. (40859.)
 (4) Hematite, chalcopryrite, quartz. Caledonia Mine. (40861.)
 (5) Hematite, containing calcite. Keene Mine. (40858.)

JEFFERSON COUNTY.

Six specimens represent the Old Sterling Mine, Antwerp.

- (1) Very impure hematite. June 23, 1881. (43745.)
 (2) Hematite, containing calcite. June 23, 1881. (43744.)
 (3) Hematite, quartz. June 23, 1881. (43743.)
 (4) Hematite. June 21, 1881. (40869.)
 (5) Decomposed mica. June 20, 1881. (43741.)
 (6) Slickenside. June 20, 1881. (43742.)
 (1) Hematite. Shurtliff Mine, Philadelphia. June 22, 1881. (40825.)

ONEIDA COUNTY.

Nine specimens represent the fossil ores of Oneida County, the first seven being from the Well's Mine at Kirkland; taken June 16, 1881:

- (1) Hematite. (43752.)
- (2) Hematite, scattered grains in limestone. (43746.)
- (3) Hematite. (43749.)
- (4) Hematite. (40935.)
- (5) Hematite. (43747.)
- (6) Hematite, containing some calcareous fossils. (43748.)
- (7) Hematite, calcite, and pyrite. (43754.)
- (8) Hematite, containing many calcareous fossils. Klein's Mine, Verona. (40941.)
- (9) Hematite, containing pyrite. Kirkland Iron Company's Mine, Westmoreland. (40936.)

WAYNE COUNTY.

Two specimens represent the fossil ore of Wayne County, Ontario:

- (1) Hematite. Bundy's Mine. June 17, 1881. (40947.)
- (2) Hematite. Hurley's Mine. June 17, 1881. (40949.)

COLUMBIA COUNTY.

- (1) Limonite. Copake Mine, Copake. September 2, 1880. (40876.)
- (2) Siderite. Hudson River Spathic Iron Company's Mine, Catskill Station. September 21, 1880. (40677.)

DUTCHESS COUNTY.

Five specimens represent the Manhattan Mine at Sharon Station; taken August 28, 1881:

- (1) Limonite. (40864.)
- (2) Limonite. (40880.)
- (3) Limonite. (40881.)
- (4) Impure limonite. (40889.)
- (5) Limonite. (40888.)
- (1) Limonite. Little Pond Mine, Pawling. August 23, 1880. (40885.)
- (2) Siderite and limonite. Amenia Mine, Amenia. August 26, 1880. (40882.)
- (3) Limonite. Amenia Mine, Amenia. August 26, 1880. (40884.)
- (4) Limonite. Dover Furnace, Dover. August 25, 1880. (40875.)
- (5) Limonite. Clove Spring Mine, Union Vale. August 24, 1880. (40886.)

PUTNAM COUNTY.

Thirty specimens represent the complex and interesting ore of the Tilly Foster Mine at Southeast; taken August 20, 1880:

- (1) Magnetite. (43726.)
- (2) Magnetite, containing serpentine and decomposed products. (40793.)
- (3) Magnetite. (43724.)
- (4) Magnetite. (43732.)
- (5) Magnetite, chondrodite, decomposed products. (43730.)
- (6) Magnetite, chloritic material. (40790.)
- (7) Magnetite. (40792.)
- (8) Magnetite, chlorite. (40801.)
- (9) Magnetite, serpentine, pyrrhotite. (40797.)
- (10) Magnetite, a mixture of large cleavable grains with fine granular, next to hanging wall. (40806.)

- (11) Magnetite, serpentine, decomposed products; from centre of vein. (40804.)
- (12) Magnetite. (40798.)
- (13) Magnetite, containing serpentine, and decomposition products. (40805.)
- (14) Magnetite. (40802.)
- (15) Magnetite. (40803.)
- (16) Magnetite, serpentine, decomposition products. (40826.)
- (17) Magnetite, chlorite. (40808.)
- (18) Magnetite, chondrodite, decomposition products. (40817.)
- (19) Magnetite. (40799.)
- (20) Magnetite, chlorite. (40800.)
- (21) Magnetite and chondrodite. (40807.)
- (22) Gangue, containing some magnetite. (40791.)
- (23) Chloritic rock, containing a little magnetite. (40796.)
- (24) Chloritic rock. (43731.)
- (25) Chlorite, showing slickenside, from hanging wall. (43728.)
- (26) Chloritic rock, from foot wall. (43733.)
- (27) Chloritic rock, from foot wall. (43723.)
- (28) Country rock. (43735.)
- (29) Country rock. (43729.)
- (30) Country rock. (40789.)

ORANGE COUNTY.

The magnetites of Orange County are represented by seven specimens:

- (1) Magnetite, containing pyrite and chalcopyrite. Hogan Camp Mine, Monroe. July 8, 1880. (40910.)
- (2) Magnetite, cleavable. Hogan Camp Mine, Monroe. July 8, 1880. (40917.)
- (3) Magnetite, containing pyrrhotite, chalcopyrite, and chlorite. Redback Mine, Monroe. June 22, 1880. (40919.)
- (4) Magnetite, quartz, feldspar. Forest of Dean Mine, Monroe. July 9, 1880. (40924.)
- (5) Magnetite, fine grained. Forest of Dean Mine, Monroe. July 9, 1880. (40926.)
- (6) Magnetite, quartz, feldspar. Forest of Dean Mine, Monroe. July 9, 1880. (40913.)
- (7) Impure magnetite. Lake Mine, Warwick. June 22, 1880. (40920.)

RICHMOND COUNTY.

The ores on Staten Island, Richmond County, are represented by eight specimens, the first four from Tyson's Four Corners Mine, and the last four from Tyson's Hill Mine, taken July 31, 1880:

- | | |
|---|---|
| (1) Limonite. (40933.) | (1) Serpentine, below the ore. (40934.) |
| (2) Limonite. (40930.) | (2) Limonite, small, globular. (40932.) |
| (3) Limonite, red ochre; used for paint. (40606.) | (3) Limonite. (40929.) |
| (4) Limonite, red ochre; used for paint. (40953.) | (4) Limonite. (40931.) |

NEW JERSEY.

SUSSEX COUNTY.

- (1) Magnetite, containing quartz. Roberts Mine, Sparta. April 17, 1880. (41454.)
- (2) Magnetite. Roberts Mine, Sparta. April 17, 1880. (41457.)
- (3) Magnetite, containing quartz. Roberts Mine, Sparta. April 17, 1880. (41453.)

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- (4) Magnetite, quartz, decomposed feldspar, pyrite. Davenport Mine, Sparta. April 17, 1880. (41459.)
- (5) Magnetite. Pardee Mine, Sparta. April 17, 1880. (41458.)
- (6) Magnetite, pyrrhotite. Hude or Stanhope Mine, Byram. April 27, 1880. (41445.)
- (7) Magnetite. Hude or Stanhope Mine, Byram. April 27, 1880. (41443.)
- (8) Magnetite, surface specimen. Hude or Stanhope Mine, Byram. April 27, 1880. (41444.)

Nine specimens represent the Andover Mine, at Andover, taken March 6, 1880:

- (1) Magnetite, surface specimen. (41463.)
- (2) Magnetite, containing quartz and pyrite. (41464.)
- (3) Magnetite, pyrrhotite. (41462.)
- (4) Magnetite, decomposed. (41465.)
- (5) Magnetite. (41461.)
- (6) Magnetite, pyrrhotite. (41460.)
- (7) Magnetite, pyrrhotite. (40608.)
- (8) Magnetite and dolomite, containing pyrite and graphite. (40641.)
- (9) Magnetite, roasted. (40587.)
- (1) Impure magnetite. Glenden Mine, Green, March 2, 1880. (40630.)
- (2) Magnetite, quartz, feldspar. Glenden Mine, Green, March 2, 1880. (40626.)
- (3) Magnetite, chloritic material. Hill Mine, Franklin Furnace. March 10, 1880. (41452.)
- (4) Magnetite, quartz, decomposed feldspar, pyrrhotite and graphite. Furnace Vein Mine, Franklin Furnace. March 12, 1880. (41449.)
- (5) Magnetite, feldspar, chalcopyrite and graphite. Furnace Vein Mine, Franklin Furnace. March 10, 1880. (41494.)

PASSAIC COUNTY.

- (1) Magnetite. Peters Mine, Pompton. June 18, 1880. (40649.)
- (2) Magnetite, quartz. Peters Mine, Pompton. February 9, 1880. (40632.)
- (3) Magnetite, quartz, feldspar. Cannon Mine, Pompton. June 1, 1880. (40657.)
- (4) Magnetite. Hope Mine, Pompton. June 18, 1880. (40645.)
- (5) Magnetite. Hope Mine, Pompton. June 18, 1880. (40658.)

MORRIS COUNTY.

Ten specimens represent the Hacklebarney Mine at Chester; taken May 8-10, 1880:

- | | |
|--|--------------------------------------|
| (1) Magnetite, pyrrhotite. (41475.) | (5) Magnetite. (40579.) |
| (2) Magnetite, pyrrhotite. (41477.) | (6) Magnetite, pyrrhotite. (41478.) |
| (3) Magnetite, containing pyrite, and chlorite. (41479.) | (7) Magnetite, pyrrhotite. (40568.) |
| (4) Magnetite, containing much pyrite. (41480.) | (8) Impure magnetite. (40614.) |
| | (9) Magnetite, pyrrhotite. (40570.) |
| | (10) Magnetite, pyrrhotite. (41476.) |

Six specimens represent the Byram Mine at Randolph; taken May 21, 1880:

- | | |
|--|---|
| (1) Magnetite, quartz, feldspar. (40553.) | (4) Magnetite, containing quartz and feldspar. (40595.) |
| (2) Magnetite, decomposed feldspar. (40598.) | (5) Magnetite, feldspar. (40627.) |
| (3) Magnetite, coarsely cleavable. (40596.) | (6) Magnetite, and decomposed silicates. (40593.) |

Six specimens represent the Glendon Mine at Rockaway; taken June 10, 1880:

- | | |
|--------------------------------|-------------------------|
| (1) Magnetite. (40564.) | (4) Magnetite. (40562.) |
| (2) Magnetite. (40648.) | (5) Magnetite. (40566.) |
| (3) Impure magnetite. (40567.) | (6) Magnetite. (40558.) |

Five specimens represent the Andover Mine at Rockaway; taken June 11, 1880:

- | | |
|---|---|
| (1) Magnetite, containing chlorite and quartz. (40559.) | (4) Magnetite, feldspar. (40659.) |
| (2) Impure magnetite. (40646.) | (5) Magnetite, coarsely cleavable. (40561.) |
| (3) Impure magnetite. (40560.) | |

(1) Magnetite, chlorite. Willis Mine, Rockaway. June 11, 1880. (40563.)

(2) Magnetite. Willis Mine, Rockaway. June 11, 1880. (40565.)

Five specimens represent the Mount Hope Mine at Rockaway; taken June 4, 1880:

- | | |
|---------------------------------------|--|
| (1) Magnetite, and feldspar. (40549.) | (4) Magnetite (40552.) |
| (2) Magnetite, and feldspar. (40550.) | (5) Magnetite, feldspar, quartz, and decomposed micaceous material. (40547.) |
| (3) Magnetite, and feldspar. (40548.) | |

(1) Magnetite, quartz, and feldspar. Richard Mine, Shaft No. 7, Rockaway. June 1, 1880. (40557.)

(2) Magnetite, quartz, and feldspar. Richard Mine, Shaft No. 3, Rockaway. June 1, 1880. (40556.)

(3) Impure magnetite. Richard Mine, Shaft No. 3, Rockaway. June 1, 1880. (40554.)

(4) Magnetite, containing quartz and feldspar. Richard Mine, Shaft No. 7, Rockaway. June 3, 1880. (40555.)

(5) Magnetite, and decomposed silicates, surface ore. Baker Mine, Randolph. May 28, 1880. (40625.)

(6) Magnetite, quartz, and decomposed feldspar. Baker Mine, Randolph. May 25, 1880. (40577.)

(7) Magnetite, pyrrhotite. Samson Mine, Chester. May 11, 1880. (41481.)

(8) Decomposition products, surface ore. Taylor Mine, Chester. May 11, 1880. (40612.)

(9) Magnetite. Hurd Mine, Jefferson. April 20, 1880. (41470.)

(10) Magnetite. Hurd Mine, Jefferson. April 20, 1880. (41469.)

(11) Magnetite, coarse, granular. Hurd Mine, Jefferson. April 20, 1880. (41466.)

(12) Magnetite, decomposed silicates, surface specimen. Mount Olive Mine, Mount Olive. April 28, 1880. (41472.)

(13) Magnetite, decomposed feldspar. Mount Olive Mine, Mount Olive. April 28, 1880. (41474.)

(14) Magnetite, pyrrhotite. Mount Olive Mine, Mount Olive. April 28, 1880. (41473.)

WARREN COUNTY.

(1) Limonite. Shields Mine, Mansfield, April 28, 1880. (41432.)

(2) Limonite. Shields Mine, Mansfield. April 28, 1880. (41433.)

(3) Siliceous clay. Shields Mine, Mansfield. April 28, 1880. (41426.)

Four specimens represent the ore at Oxford Furnace, New Mine, taken February 10, 1880:

- | | |
|--------------------------------|--------------------------------|
| (1) Magnetite. (41434.) | (3) Magnetite. (41436.) |
| (2) Impure magnetite. (41435.) | (4) Impure magnetite. (41437.) |

- (1) Impure magnetite. Pequest Mine. February 10, 1880. (40637.)
- (2) Impure magnetite. Kishpangh Mine. February 12, 1880. (41440.)
- (3) Magnetite. Kishpangh Mine. February 12, 1880. (41441.)
- (4) Magnetite. Kishpangh Mine. February 12, 1880. (40607.)

HUNTERDON COUNTY.

Six specimens represent the Hayer Mine at Holland, taken May 4, 1880:

- (1) Magnetite, surface specimen. (41490.)
- (2) Magnetite, decomposed products, surface specimen. (41487.)
- (3) Magnetite, surface specimen. (41491.)
- (4) Magnetite, granular, surface specimen. (41488.)
- (5) Magnetite, surface specimen. (41492.)
- (6) Magnetite, surface specimen. (41489.)
- (1) Magnetite, quartz, decomposition products. Gray's Mine, Lebanon. May 3, 1880. (40653.)
- (2) Magnetite, pyrrhotite, quartz, decomposition products. Gray's Mine, Lebanon. May 3, 1880. (40605.)
- (3) Decomposed magnetite, and quartz, surface specimen. Gray's Mine, Lebanon. May 3, 1880. (40636.)

PENNSYLVANIA.

LEHIGH COUNTY.

Four specimens represent the Balliet Brothers Mine, at Whitehall, taken October 19, 1881:

- (1) Limonite. (40692.)
- (2) Impure limonite, liver ore. (40700.)
- (3) Limonite, commonly called pipe ore. (40697.)
- (4) Limonite. (40703.)

BERKS COUNTY.

Ten specimens represent the Warwick mine at Boyerstown, taken July 2, 1881:

- (1) Magnetite, and calcite containing pyrite. (41884.)
- (2) Magnetite, pyrite crystallized, calcite crystallized. (41885.)
- (3) Calcite, pyrite. (41886.)
- (4) Decomposed epidote rock. (43700.)
- (5) Rock. (43699.)
- (6) Chloritic rock, from upper level. (43698.)
- (7) Rock, hanging wall of upper vein. (43595.)
- (8) Chloritic rock, from bottom of shaft. (43594.)
- (9) Argillaceous rock, from lower level. (40676.)
- (10) Selvage between ore and hanging wall, bottom level. (43697.)

Seven specimens represent the Fritz Island Mine, near Reading; taken June 24, 1881:

- (1) Magnetite, pyrite, and calcite. (41877.)
- (2) Magnetite, containing much pyrite. (41878.)
- (3) Impure magnetite. (41879.)
- (4) Foot wall. (41880.)
- (5) Hanging wall. (41881.)
- (6) Hanging wall. (41882.)
- (7) Rock, from between the ore bodies. (41883.)

Eleven specimens represent the French Creek Mine:

- (1) Magnetite, pyrite, and calcite. Shaft No. 1. (41907.)
- (2) Magnetite, micaceous, pyrite undergoing decomposition. Shaft No. 1. (41894.)
- (3) Magnetite, pyrite, and calcite. Shaft No. 1. (41895.)
- (4) Granitic rock, hanging wall. Shaft No. 1. (43611.)
- (5) Calcite, inclosing granite rock, hanging wall. Shaft No. 1. (43610.)
- (6) Trap rock, in west wall. (43612.)
- (7) Quartzite, east wall. Shaft No. 1. (43856.)
- (8) Granitic rock, foot wall. Shaft No. 1. (43609.)
- (9) Magnetite, containing calcite, and pyrite. Shaft No. 2. (41908.)
- (10) Magnetite, pyrite crystals, octahedrons, chloritic material. Shaft No. 2. (40689.)
- (11) Hanging wall. Shaft No. 2. (40690.)

Three specimens represent the Barto Mine, at Barto, taken July 5, 1881:

- (1) Magnetite, containing pyrite. (41892.)
- (2) Granite rock, showing slickensides, wall rock. (41893.)
- (3) Epidote rock. (40686.)

Five specimens represent the Hopewell Mine, at St. Mary's, taken July 13, 1881:

- (1) Magnetite, containing octahedral crystals. (41897.)
- (2) Magnetite, containing pyrite, and calcite. (41898.)
- (3) Quartzite, foot wall. (41938.)
- (4) Granitic rock, coarse; wall rock. (41940.)
- (5) Trap rock. (41939.)
- (1) Limonite, pipe ore. Frank Brownback Mine, Long Swamp. October 18, 1880. (40709.)
- (2) Magnetite, pyrite, decomposed silicates; immediately below the limestone, Jones Mine. (41905.)
- (3) Magnetite, pyrite, chalcopryrite, and dolomite. Jones Mine. (41909.)
- (4) Magnetite, quartz, and feldspar. Mine Hill Mine, Durham. October 20, 1880. (40706.)

CHESTER COUNTY.

Four specimens represent the Stauffer's Mine, at West Vincent, taken June 22, 1881.

- (1) Limonite, geode. (40693.)
- (2) Limonite. (40682.)
- (3) Limonite, cementing quartz pebbles. (41936.)
- (4) Limonite and quartz. (40711.)

LEBANON COUNTY.

Ten specimens represent the Great Cornwall Mines, taken June 18, 1881.

- (1) Magnetite, containing much pyrite. (42297.)
- (2) Impure banded magnetite, with pyrite. (40684.)
- (3) Magnetite, containing pyrite. (41902.)
- (4) Magnetite, containing pyrite, and decomposed silicates. (43712.)
- (5) Impure magnetite, pyrite. (43716.)
- (6) Calcite. (41903.)
- (7) Pyrite, crystallized, with magnetite. (40680.)

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- (8) Limestone, associated with ore. (43714.)
- (9) Trap rock. (43708.)
- (10) Hydro-mica slate, associated with the ore. (41901.)

LANCASTER COUNTY.

- (1) Limonite. Chestnut Hill Mine, West Hempfield. October 10, 1881. (40673.)

LYCOMING COUNTY.

- (1) Hematite, fossil ore. P. H. Hayes' Mine, Cogan Station. October 5, 1881. (41955.)
- (2) Hematite, fossil ore. P. R. Hayes' Mine, Cogan Station. October 5, 1881. (40663.)

MONTOUR COUNTY.

- (1) Hematite, commonly called block ore. Danville Mine. October 5, 1881. (41923.)
- (2) Hematite, commonly called block ore. Danville Mine. October 5, 1881. (41924.)
- (3) Hematite, calcite; limestone ore. Danville Mine. October 5, 1881. (41925.)

SNYDER COUNTY.

- (1) Hematite, bird's eye fossil ore. Kreamer Station. October 5, 1881. (40662.)
- (2) Hematite, fossil ore. Beavertown Mine. October 5, 1881. (41950.)

YORK COUNTY.

- (1) Magnetite, containing much pyrite. Longnecker Mine, near Dillsburgh. July 20, 1881. (40671.)
- (2) Impure magnetite, pyrite, and calcite. Longnecker Mine, near Dillsburgh. July 20, 1881. (41918.)
- (3) Limonite. Fritz Mine, York. July 16, 1881. (41910.)
- (4) Limonite. Fritz Mine, York. July 16, 1881. (41911.)
- (5) Impure magnetite. Codorus Mine, Hanover Junction. July 18, 1881. (40687.)
- (6) Hematite, containing crystals of altered magnetite. MARTITE. Codorus Mine, Hanover Junction. July 18, 1881. (40660.)
- (7) Decomposed rock, showing casts of crystals of magnetite. Codorus Mine, Hanover Junction. July 18, 1881. (40668.)
- (8) Hydro-mica slate. Codorus Mine, Hanover Junction. July 15, 1881. (41915.)

CUMBERLAND COUNTY.

- (1) Limonite, pipe ore. Carlisle Mine, South Middleton. October 18, 1881. (40664.)
- (2) Limonite. Carlisle Mine, South Middleton, October 7, 1881. (40694.)
- (3) Limonite. Pine Grove Mine No. 1, Cooke. October 7, 1881. (41954.)

HUNTINGDON COUNTY.

- (1) Limonite. Sandy Ridge Mine, Cromwell. October 4, 1881. (41945.)
- (2) Limonite. Sandy Ridge Mine, Cromwell. October 4, 1881. (41944.)
- (3) Roasted ore. Sandy Ridge Mine, Cromwell. October 4, 1881. (41943.)
- (4) Limonite. Douglass Mine, Shirly. October 4, 1881. (41942.)

BLAIR COUNTY.

- (1) Siliceous limonite. Springfield Mine, Huston. September 29, 1881. (41926.)
- (2) Hematite, fossil ore. Frankstown Mine, Frankstown. September 29, 1881. (41927.)

- (3) Impure limonite. Bloomfield Mine, Taylor. September 30, 1881. (41928.)
- (4) Impure limonite. Bloomfield Mine, Taylor. September 30, 1881. (41929.)
- (5) Roasted ore. Bloomfield Mine, Taylor. September 30, 1881. (41930.)

BEDFORD COUNTY.

- (1) Hematite, containing calcite. Hard fossil ore. Walter's Mine, Bedford. September 28, 1881. (40666.)
- (2) Hematite. Soft fossil ore. Yatesville Mine, Hopewell. September 28, 1881. (41941.)

FAYETTE COUNTY.

- (1) Siderite. Dunbar Mine, Dunbar. September 27, 1881. (41933.)
- (2) Roasted siderite. Dunbar Mine, Dunbar. September 28, 1881. (41932.)
- (3) Siderite. Beauvaller Mine, Dunbar. September 28, 1881. (41931.)

DELAWARE.

NEW CASTLE COUNTY.

- (1) Limonite. Iron Hill Mine. April 20, 1881. (42254.)
- (2) A brick made by washing, pressing, and burning the raw ore. East Chestnut Hill Mine. April 20, 1881. (42255.)

MARYLAND.

BALTIMORE COUNTY.

- (1) Siderite and limonite. Jacob Smith's Mine. April 30, 1881. (42223.)
- (2) Siderite. Spring Garden Mine. Baltimore. January 14, 1881. (42222.)
- (3) Limonite. Green Springs Mine. May, 1881. (42237.)
- (4) Limonite. J. Odenso's Mine. May, 1881. (42230.)
- (5) Siderite. Hone ore. Furstenburg Mine. April 30, 1881. (42224.)
- (6) Limonite, fibrous coating of cavity. Oregon Mine. May, 1881. (42236.)

ANNE ARUNDEL COUNTY.

- (1) Impure limonite. Mitchell's Mine. May, 1881. (42204.)

HOWARD COUNTY.

- (1) Impure limonite. Hanover Switch Mine, Hanover. January 7, 1881. (42239.)

PRINCE GEORGE'S COUNTY.

- (1) Limonite. Frieb & Millbrook's Mine. May 1, 1881. (42213.)
- (2) Limonite. James O'Brien Mine. May, 1881. (42215.)

CARROLL COUNTY.

- (1) Magnetite, containing quartz. Springfield Mine, near Sykesville. May, 1881. (42246.)
- (2) Limonite. Avondale Mine, near Westminster, May, 1881. (42243.)

FREDERICK COUNTY.

- (1) Limonite. Grim's Mine, near New Midway. June, 1881. (42219.)

ALLEGANY COUNTY.

- (1) Limonite. Bowery Mine, near Borden Shaft. June, 1881. (41352.)

VIRGINIA.

NELSON COUNTY.

- (1) Hematite and magnetite. Greenway Mine, Greenway. May 7, 1880. (40383.)

AMHERST COUNTY.

- (1) Hematite and magnetite. Adams & Scott's Mine, vein No. 13, Riversville. May 6, 1880. (40395.)

- (2) Hematite and magnetite, containing opal. Stapleton Mine, Stapleton. April 28, 1880. (40381.)

CAMPBELL COUNTY.

- (1) Limonite, containing quartz. Williams' Mine. June 10, 1880. (40386.)

FRANKLIN COUNTY.

- (1) Magnetite. Rocky Mount Mine, Rocky Mount. May 26, 1880. (40396.)

PITTSYLVANIA COUNTY.

- (1) Limonite, containing much manganese. Pittsville Mine. May 27, 1880. (41323.)

SHENANDOAH COUNTY.

- (1) Limonite, containing manganese. West Mine, near Van Buren Furnace. August 10, 1880. (43783.)

- (2) Limonite. Hollow Mine. August 12, 1880. (42132.)

- (3) Limonite. Three Top Mountain Mine. August 11, 1880. (42127.)

ROCKINGHAM COUNTY.

- (1) Limonite. Fox Mountain Mine. August 5, 1880. (42120.)

- (2) Limonite. Raines & Weaver Mine. August 16, 1880. (42123.)

AUGUSTA COUNTY.

- (1) Limonite. Ferrol Mine, Ferrol. July 29, 1880. (42152.)

- (2) Limonite. Mt. Torrey Furnace Mine. July 30, 1880. (42155.)

- (3) Limonite. Buffalo Gap Mine. July 28, 1880. (42151.)

ALLEGHANY COUNTY.

- (1) Limonite. Hudleson's Mine, near Covington. December 4, 1880. (42113.)

- (2) Limonite. Dolly Ann Furnace, near Covington. December 18, 1880. (42119.)

Four specimens represent the Lowmoor Mine, at Lowmoor; taken July 21, 1880:

- (1) Limonite. (43794.)

- (3) Limonite. (43782.)

- (2) Limonite. (43795.)

- (4) Limonite. (42106.)

- (1) Limonite. Lucy Selina Furnace. July 14, 1880. (40417.)

- (2) Limonite. Lucy Selina Furnace. July 14, 1880. (42101.)

- (3) Limonite. Lucy Selina Furnace. July 14, 1880. (40416.)

- (4) Hematite, fossil ore. Quinnemont Mine, Clifton Forge. July 19, 1880. (42104.)

BOTETOURT COUNTY.

- (1) Hematite, containing much quartz. Arcadia Mine, near Buchanan. July, 1880. (43787.)

- (2) Limonite. Arcadia Furnace Mine. July 7, 1880. (40411.)

- (3) Limonite. Salisbury Furnace, near Saltpetre Cave. November 30, 1880. (42175.)

PULASKI COUNTY.

- (1) Limonite. Rich Hill Mine, Allisonia. June 22, 1880. (40403.)

WYTHE COUNTY.

- (1) Limonite. Glade Mine, near Wytheville. June 23, 1880. (40399.)
 (2) Limonite. Noble Mine, near Brown Hill Forge. July 1, 1880. (42139.)
 (3) Limonite, containing quartz. Chadwick Mine, near Brown Hill Furnace. (43791.)
 (4) Limonite. Carter Furnace, near Wytheville. June 21, 1880. (40404.)

NORTH CAROLINA.

ROCKINGHAM COUNTY.

- (1) Impure magnetite. Daunemora Mine near Brown's Summit. (43597.)

STOKES COUNTY.

- (1) Magnetite. Roger's Mine, Danbury. (41283.)
 (2) Impure magnetite. Roger's Mine, Danbury. (41286.)

SURRY COUNTY.

- (1) Magnetite, and decomposed silicates. Ferris Mine, near Hyatt's Forge. (43864.)
 (2) Magnetite, obtained by crushing and washing No. 43864. Hyatt's Mine, Bull Run Creek. March 22, 1880. (41261.)

ASHE COUNTY.

- (1) Impure magnetite. N. B. Ballow's Mine, Holton Creek. July 22, 1880. (41218.)
 (2) Magnetite. J. Graybeal's Mine, Horse Creek. July 21, 1880. (41209.)

MITCHELL COUNTY.

- (1) Impure magnetite. Cranberry Mine. May 31, 1880. (41188.)
 (2) Magnetite. Iron Mountain Mine. May 4, 1880. (41288.)

CHEROKEE COUNTY.

- (1) Limonite. Section No. 6, near Murphy. May 11, 1880. (41203.)

GASTON COUNTY.

- (1) Limonite, containing quartz. Mine Mountain Mine, near King's Mountain. April 10, 1880. (41183.)
 (2) Martite, sesquioxide of iron pseudomorph after magnetite. Surface ore. Crowder's Mountain Mine. April 12, 1880. (41208.)

CHATHAM COUNTY.

- (1) Siderite, containing carbonaceous matter; blackband ore. Horton's Coal Mine, Gulf. (43873.)
 (2) Limonite. Ore Hill Mine, 90-foot shaft. (41282.)
 (3) Hematite. Smith Mine, Lockville. (43865.)

NASH COUNTY.

- (1) Limonite. Bloomsy Mine, near Wilson. (41285.)

GEORGIA.

FANNIN COUNTY.

- (1) Turgite. Jarrett's Mine, near Morgantown. May 13, 1880. (40473.)

MURRAY COUNTY.

- (1) Limonite, containing quartz. Calico Mine, Aliculsic Valley. June 15, 1880. (40463.)
 (2) Limonite. Harris Mine, near Spring Place. June 11, 1880. (40467.)

WHITFIELD COUNTY.

- (1) Hematite, fossil ore. Holland's Mine, near Dalton. June 13, 1880. (40469.)

FLOYD COUNTY.

- (1) Limonite. Ridge Valley Furnace, near Rome. June 1, 1880. (40483.)
 (2) Limonite. Ridge Valley Mine, near Rome. June 2, 1880. (40476.)

BARTOW COUNTY.

- (1) Manganese ore. Manganite. Black Mine, Cartersville. June 7, 1880. (40527.)
 (2) Manganese ore. Manganite. Dobbins Mine, near Cartersville. June 7, 1880. (40509.)
 (3) Manganese ore. Manganite. Dobbins Mine, near Cartersville. June 7, 1880. (40532.)
 (4) Manganese ore. Impure manganite. Chumbler Hill Mine, near Cartersville. June 7, 1880. (42293.)
 (5) Manganese ore. Impure manganite. Cooper Mine. June 8, 1880. (40517.)
 (6) Manganese ore. Impure manganite. Moccasin Mine, near Cartersville. June 7, 1880. (42294.)
 (7) Manganese ore. Impure manganite. Stephens Mine, near Cartersville. June 8, 1880. (40528.)
 (8) Hematite; specular ore. Gray Mine, Cartersville. June 8, 1880. (40514.)
 (9) Limonite. Wheeler Mine, near Bartow Furnace. May 24, 1880. (40511.)
 (10) Limonite. Crow Mine, near Wheeler's Bank. May 20, 1880. (40487.)
 (11) Limonite. Crow Mine, near Wheeler's Bank. May 20, 1880. (40489.)
 (12) Limonite. Crow Mine, near Wheeler's Bank. May 20, 1880. (40485.)
 (13) Limonite. Bartow Furnace, near Cartersville. May 24, 1880. (40539.)
 (14) Limonite. Bartow Furnace, near Cartersville. May 24, 1880. (40526.)
 (15) Limonite. Etowah Mine, near Cartersville. June 7, 1880. (40512.)
 (16) Turgite. Wild Cat Mine, near Cartersville. May 21, 1880. (40531.)
 (17) Limonite. Big Mine. May 21, 1880. (40544.)
 (18) Limonite. Connor Mine. May 21, 1880. (40543.)
 (19) Limonite. Peach Tree Mine, near Diamond Furnace. May 21, 1880. (40504.)

POLK COUNTY.

- (1) Impure limonite. Fisher's Creek Mine, near Cedartown. May 29, 1880. (40479.)
 (2) Limonite. Peek Mine, Cedartown. May 28, 1880. (40484.)
 (3) Limonite. Peek Mine, Cedartown. May 28, 1880. (40482.)
 (4) Limonite. Pennington Mine, Etna Furnace. May 31, 1880. (40495.)
 (5) Limonite. Wood's Mine, Cedartown. May 27, 1880. (40497.)
 (6) Limonite. Wood's Mine, Cedartown. May 27, 1880. (40496.)

CHEROKEE COUNTY.

- (1) Limonite, containing quartz. Donaldson's Mine, near Canton. May 18, 1880. (40488.)

ALABAMA.

CHEROKEE COUNTY.

- (1) Limonite. Tecumseh Mine. February 23, 1880. (43608.)
- (2) Limonite. Jacksonville Mine, Tecumseh. February 23, 1880. (41136.)
- (3) Limonite. Harden Mine, Rock Run. February 24, 1880. (41129.)
- (4) Limonite. Stonewall Mine. February 23, 1880. (41139.)
- (5) Hematite, fossil ore. Round Mountain Mine. March 5, 1880. (41123.)

ETOWAH COUNTY.

- (1) Hematite, fossil ore. Atalla Mine. March 9, 1880. (41106.)
- (2) Hematite, calcite. Atalla Mine. March 9, 1880. (41125.)
- (3) Hematite, fossil ore. Rising Fawn Mine, Atalla. March 6, 1880. (41120.)
- (4) Hematite, fossil ore. Pittsburg Mine. (41178.)

CALHOUN COUNTY.

- (1) Limonite. Pendergrass Mine, near Oxford. April 12, 1880. (41162.)

ST. CLAIR COUNTY.

- (1) Hematite, fossil ore. St. Clair Mine. February 9, 1880. (41148.)

TALLADEGA COUNTY.

- (1) Limonite. Alabama Company's Mine. February 19, 1880. (41112.)
- (2) Limonite. Clifton Mine. February 20, 1880. (41101.)
- (3) Limonite. Clifton Mine. February 20, 1880. (41115.)
- (4) Limonite. Caldwell Mine, Clifton. February 20, 1880. (41158.)
- (5) Limonite. Seay Mine. February 20, 1880. (41130.)
- (6) Limonite. Seay Mine, Alabama Furnace. February 20, 1880. (41113.)

JEFFERSON COUNTY.

- (1) Hematite, called fossil ore. Eureka Mine. February 4, 1880. (41146.)
- (2) Hematite. Eureka Mine, Eureka. February 4, 1880. (41127.)
- (3) Hematite, fossil ore. Red Mountain Mine. February 8, 1880. (40019.)
- (4) Hematite, fossil ore. Red Mountain Mine. February 8, 1880. (41145.)
- (5) Hematite, fossil ore. Potter's Mine. February 28, 1880. (41104.)
- (6) Siderite, containing carbonaceous matter; blackband ore. New Castle Mine, New Castle. February 6, 1880. (41138.)

SHELBY COUNTY.

- (1) Limonite. Shelby Mine. February 18, 1880. (41140.)
- (2) Limonite, in long fibers. Shelby Mine. February 18, 1880. (41111.)

TUSCALOOSA COUNTY.

- (1) Hematite, fossil ore. Alice Furnace. February 14, 1880. (41102.)
- (2) Impure limonite. Tuscaloosa Mine. February 14, 1880. (41154.)

BIBB COUNTY.

- (1) Limonite. Edwards Mine. February 13, 1880. (41122.)
- (2) Limonite. Edwards Mine. February 13, 1880. (41157.)

FRANKLIN COUNTY.

- (1) Limonite. Russellville. April 13, 1881. (41164.)
- (2) Limonite. Russellville. April 13, 1881. (41163.)

LAMAR COUNTY.

- (1) Limonite. Old Iron Works, near Vernon. April 16, 1881. (41170.)

TENNESSEE.

JOHNSON COUNTY.

- (1) Limonite. Baker Mine, Roane Creek. July 25, 1880. (41996.)
 (2) Limonite. Laurel Fork Mine, near Taylorsville. July 24, 1880. (41988.)
 (3) Limonite. Donnelly's Mine, Shann's Cross Roads. July 24, 1880. (41991.)
 (4) Limonite. Mountain Mine, Little Doe Creek. July 20, 1880. (41994.)
 (5) Manganese ore. Manganite. Silver Mine, Shady Valley. July 20, 1880.
 (42003.)
 (6) Limonite. Washington Place Mine, Little Doe Creek. July 19, 1880. (41976.)

SULLIVAN COUNTY.

- (1) Limonite. Crockett Mine, near Bristol. July 28, 1880. (42080.)

CARTER COUNTY.

- (1) Limonite. Blevin's Mine, near Stony Creek. July 29, 1880. (42020.)
 (2) Manganese ore. Manganite. Cedar Hill Mine, near Elizabeton. July 18,
 1880. (42011.)
 (3) Limonite. Hodge Mine, near Stony Creek. July 29, 1880. (42025.)
 (4) Limonite. Hurley Mine, near Stony Creek. July 29, 1880. (42017.)
 (5) Limonite. Red Shear Mine, near Stony Creek. July 29, 1880. (42032.)
 (6) Limonite. Specular Mine, near Stony Creek. July 29, 1880. (42030.)

WASHINGTON COUNTY.

- (1) Limonite. Lead Mine, Bompas Cove. July 15, 1880. (40992.)
 (2) Limonite. Main Mine, Bompas Cove. July 14, 1880. (42053.)

UNICOI COUNTY.

- (1) Limonite. Blue Springs Mine, near Indian Creek. July 16, 1880. (41022.)
 (2) Limonite. Keener Mine, Greasy Cove. July 16, 1880. (40991.)
 (3) Limonite. Greasy Cove. July 16, 1880. (41023.)

GREENE COUNTY.

- (1) Limonite. Green Ridge Mine, near Greeneville. July 12, 1880. (42078.)
 (2) Limonite. Green Ridge Mine, near Greeneville. July 12, 1880. (42076.)

HAMBLETON COUNTY.

- (1) Limonite. Vineyard Mine, near Witt's Foundry. July 5, 1880. (42068.)
 (2) Limonite. Williams' Mine, near Witt's Foundry. July 5, 1880. (42069.)

COCKE COUNTY.

- (1) Limonite. J. Mantooth's Mine, near Sweetwater. July 8, 1880. (42048.)
 (2) Hematite. W. R. Smith's Mine, Wolf Creek. July 9, 1880. (42052.)

SEVIER COUNTY.

- (1) Limonite, containing quartz. Love's Mine, near Sevierville. July 7, 1880,
 (42061.)

BLOUNT COUNTY.

- (1) Limonite. Carpenter Mine, near Maryville. June 28, 1880. (40999.)
- (2) Pyrite, showing decomposition to limonite, the probable source of the ore. Seaton Mine, near Maryville. June 28, 1880. (41021.)
- (3) Limonite, containing quartz. Razer's Mine. June 22, 1880. (41007.)
- (4) Limonite. Kerr's Mine, near Maryville. (41011.)
- (5) Limonite. Wilson Mine, near Maryville. June 28, 1880. (41015.)

MONROE COUNTY.

- (1) Manganese ore. Impure manganite. Donnelly Mine, near Tallica Furnace. June 20, 1880. (41003.)
- (2) Impure limonite. Anderson's Mine. June 21, 1880. (41001.)

MC. MINN COUNTY.

- (1) Pyrite, showing decomposition to limonite, the probable source of the ore Chas. Cate's Mine, near Athens. August 1, 1880. (42041.)
- (2) Limonite. Chas. Cate's Mine, near Athens. August 1, 1880. (42042.)
- (3) Limonite and pyrite. R. G. Patty's Mine, near Athens. August 1, 1880. (42038.)
- (4) Hematite. Sheriff Mine, near Athens. June 18, 1880. (41028.)

The fossil ores of the Tennessee River Valley are represented by the following twelve specimens:

SCOTT COUNTY.

- (1) Hematite. L. J. Stanfield's Mine, Elk Fork Valley. July 1, 1880. (42055.)

ANDERSON COUNTY.

- (1) Hematite. Lone Mountain Mine, Clinton. June 30, 1880. (41030.)

ROANE COUNTY.

- (1) Hematite. Brown's Mine. March 19, 1880. (41048.)
- (2) Hematite. Oakdale Mine, Oakdale. March 16, 1880. (41050.)
- (3) Hematite. Oakdale Mine, Oakdale. March 16, 1880. (41039.)
- (4) Hematite. Robert's Mine, Kingston. March 19, 1880. (41037.)
- (5) Hematite containing calcareous fossils. Rockwood Mine, Rockwood. March 17, 1880. (41049.)

RHEA COUNTY.

- (1) Hematite. Hill & Tarwater Mine. March 20, 1880. (43684.)
- (2) Hematite. Hill & Tarwater Mine. March 20, 1880. (41034.)

JAMES COUNTY.

- (1) Hematite. Ragon's Mine. March 10, 1880. (41032.)

HAMILTON COUNTY.

- (1) Hematite. Coker Mine, Chattanooga. March 11, 1880. (41051.)

BRADLEY COUNTY.

- (1) Hematite. Hinck Mine. March 10, 1880. (41093.)

MONTGOMERY COUNTY.

- (1) Limonite. Steel's Mine. April 20, 1880. (42046.)

STEWART COUNTY.

- (1) Limonite. Bear Springs Mine. April 14, 1880. (41074.)
- (2) Limonite. Clark Furnace. April 15, 1880. (41085.)
- (3) Turgite. Bear Springs Mine. April 14, 1880. (41075.)
- (4) Limonite. La Grange Furnace. April 16, 1880. (41087.)
- (5) Limonite. La Grange Furnace. April 17, 1880. (41084.)
- (6) Limonite. La Grange Furnace. April 15, 1880. (41081.)
- (7) Limonite. Rough and Ready Mine. April 13, 1880. (41072.)

DICKSON COUNTY.

- (1) Limonite. Cumberland Furnace. April 4, 1880. (41065.)
- (2) Impure limonite. Cumberland Furnace. April 4, 1880. (41069.)
- (3) Limonite. Piney Mine, Dickson. March 31, 1880. (41071.)

HICKMAN COUNTY.

- (1) Hematite. Aetna Mine, Centerville. March 29, 1880. (41090.)
- (2) Limonite. Mill Creek Mine, Centerville. March 31, 1880. (41089.)

LAWRENCE COUNTY.

- (1) Limonite. Napier's Mine, Napier's Furnace. May 27, 1880. (41059.)
- (2) Limonite. Napier's Mine, Napier's Furnace. March 27, 1880. (41056.)

WAYNE COUNTY.

- (1) Impure limonite. Marion Furnace, Clifton. March 28, 1880. (43686.)

KENTUCKY.

GREENUP COUNTY.

- (1) Impure limonite. Pennsylvania Furnace. July 7, 1880. (40420.)
- (2) Impure limonite. Pennsylvania Furnace. July 6, 1880. (40425.)
- (3) Limonite. Pennsylvania Furnace. July 7, 1880. (43766.)

CARTER COUNTY.

- (1) Limonite. Iron Hills Mine. July 8, 1880. (43776.)
- (2) Siderite and limonite. Mount Savage Furnace. July 9, 1880. (43774.)
- (3) Impure limonite. Mount Savage Furnace. July 10, 1880. (43775.)
- (4) Limonite. Stewart's Mine. July 9, 1880. (40436.)

LAWRENCE COUNTY.

- (1) Siderite, containing barite and limonite. Dry Fork Mine. July 10, 1880. (40452.)
- (2) Limonite. Dry Fork Mine. July 10, 1880. (43770.)

BATH COUNTY.

- (1) Limonite. Bath Furnace. June 23, 1880. (43590.)
- (2) Limonite. Old Slate Mine. June 24, 1880. (40430.)

POWELL COUNTY.

- (1) Impure siderite. Estill Furnace. June 25, 1880. (40458.)
- (2) Limonite. Estill Furnace. June 25, 1880. (43769.)

LYON COUNTY.

- (1) Limonite. Centre Furnace. June 30, 1880. (43587.)
- (2) Limonite. Centre Furnace. June 30, 1880. (40450.)

TRIGG COUNTY.

- (1) Limonite. Trigg Furnace. (43585.)

MISSOURI.

FRANKLIN COUNTY.

- (1) Impure hematite. Bennett & Thurman Mine. May 27, 1881. (43656.)

CRAWFORD COUNTY.

- (1) Hematite. Cherry Valley Mine, pit No. 2. May 10, 1880. (43659.)
- (2) Hematite. Cherry Valley Mine, pit No. 1. May 10, 1880. (40730.)
- (3) Hematite. Iron Ridge Mine. May 25, 1880. (40719.)
- (4) Hematite. Lane Mine. May 8, 1880. (40725.)
- (5) Hematite. Marsh Mine. May 25, 1880. (40724.)
- (6) Hematite. McGarvy's Mine, near Seasburg. May 26, 1880. (40723.)
- (7) Hematite. Scotia Mine. May 26, 1880. (40722.)

PHELPS COUNTY.

- (1) Hematite. Lamb Mine. May 18, 1880. (40778.)
- (2) Hematite. Horse Hollow Mine. May 23, 1880. (40765.)
- (3) Hematite. Moselle Mine. May 24, 1880. (40770.)
- (4) Hematite. Smith Mine No. 3. May 18, 1880. (40772.)

DENT COUNTY.

- (1) Hematite. Milsap Mine. May 19, 1880. (40760.)
- (2) Hematite. Nova Scotia Mine. May 20, 1880. (40738.)
- (3) Hematite. Nova Scotia Mine. May 20, 1880. (40740.)
- (4) Hematite. Pomeroy Mine. May 19, 1880. (40743.)
- (5) Hematite, called pipe ore. Watkins Mine. May 18, 1880. (40741.)
- (6) Hematite. Riverside Mine. May 20, 1880. (40757.)
- (7) Hematite. Riverside Mine. May 20, 1880. (40748.)
- (8) Hematite. Riverside Mine. May 20, 1880. (43604.)
- (9) Hematite. Orchard Mine. May 19, 1880. (40759.)
- (10) Hematite, quartz, in large crystals. Fitzwater Mine. May 21, 1880. (40746.)
- (11) Pyrite, showing decomposition to fibrous limonite. Dry Fork Mine. May 18, 1880. (40755.)
- (12) Limonite, pipe ore. Simmon's Mountain. May 19, 1880. (40753.)

IRON COUNTY.

- (1) Hematite. Cedar Mountain Mine. April 30, 1880. (40720.)
- (2) Hematite. Pilot Knob Mine. April 30, 1880. (40717.)
- (3) Hematite. Shepherd Mountain Mine. April 30, 1880. (43654.)

ST. FRANCOIS COUNTY.

Five specimens represent the celebrated Iron Mountain deposit, taken May 3, 1880 :

- | | |
|--|--|
| (1) Hematite, surface nodules. (40784.) | (4) Hematite, containing apatite. (40779.) |
| (2) Hematite. (40780.) | (5) Porphyry, in which the ore occurs. |
| (3) Hematite, containing apatite. (40781.) | (40783.) |

OHIO.

COLUMBIANA COUNTY.

- (1) Impure limonite, surrounding impure siderite. Dennon's Mine, near New Lisbon. June 8, 1881. (41367.)
- (2) Siderite, containing carbonaceous matter called blackband ore. John Henry Mines, near Mineral Ridge. June 6, 1881. (41359.)
- (3) Roasted blackband ore. John Henry Mines, near Mineral Ridge. June 6, 1881. (41358.)
- (4) Impure limonite, surrounding impure siderite. Smith's Mine, near New Lisbon. June 8, 1881. (41353.)
- (5) Impure limonite, surrounding siderite. Smith's Mine, near New Lisbon. June 8, 1881. (41356.)
- (6) Siderite, containing carbonaceous matter; blackband ore. Todd, Wells & Co.'s Mine, Mineral Ridge. June 6, 1881. (41758.)

TUSCARAWAS COUNTY.

- (1) Siderite and limonite. Anman Mine, near Dover. June 1, 1881. (41392.)
- (2) Impure limonite. Bahler Mine, near Dover. June 2, 1881. (41374.)
- (3) Siderite, containing carbonaceous matter; blackband ore. Bahler Mine, near Dover. June 2, 1881. (41378.)
- (4) Siderite, containing carbonaceous matter; blackband ore. Bahler Mine, near Dover. June 2, 1881. (43670.)
- (5) Siderite, containing carbonaceous matter; blackband ore. Dover Hill Furnace, near Zoar Station. June 2, 1881. (41379.)
- (6) Roasted blackband ore. Dover Hill Furnace, near Zoar Station. June 2, 1881. (41380.)
- (7) Impure hematite. Groebel Mine, near Dover. June 2, 1881. (41393.)
- (8) Siderite, containing carbonaceous matter; blackband ore. H. Kelly's Mine, June 2, 1881. (41383.)
- (9) Impure limonite. Heit's Mine, near Dover. June 1, 1881. (41398.)
- (10) Siderite and limonite, near Dover. (43673.)

MUSKINGUM COUNTY.

- (1) Impure limonite. Goff's Mine, Frazeysburgh. May 27, 1881. (41407.)
- (2) Impure limonite. McGinnis Mine, Frazeysburgh. May 27, 1881. (41403.)
- (3) Impure siderite. Millstead Mine, Frazeysburgh. May 27, 1881. (41400.)

PERRY COUNTY.

- (1) Limonite. Bowman Mine, Shawnee. May 24, 1881. (41811.)
- (2) Impure siderite. Donnelly Mine, Moxahala. May 24, 1881. (41416.)
- (3) Limonite. Iron Point Mine, Shawnee. May 24, 1881. (41410.)
- (4) Siderite. Junction City. May 24, 1881. (43668.)

HOCKING COUNTY.

- (1) Impure hematite, blackband ore. Gore Furnace. May 17, 1881. (41822.)
- (2) Roasted limestone ore. Gore Furnace Mine. May 17, 1881. (41824.)

ATHENS COUNTY.

- (1) Siderite, containing carbonaceous matter; blackband ore. Orbiston Furnace. May 18, 1881. (41807.)
- (2) Limonite, decomposed blackband ore. Orbiston Furnace. May 18, 1881. (41808.)

VINTON COUNTY.

- (1) Siderite and limonite. Creola Mine. May 20, 1881. (41816.)
- (2) Impure siderite. Eagle Furnace. May 20, 1881. (43630.)
- (3) Hematite. Eagle Furnace. May 20, 1881. (43676.)
- (4) Limonite. Eagle Furnace. May 20, 1881. (41820.)
- (5) Impure limonite. Eagle Furnace. May 20, 1881. (41821.)
- (6) Limonite. Creola Mine. May 20, 1881. (41815.)

JACKSON COUNTY.

- (1) Limonite. Milton Furnace, near Hamden. May 13, 1881. (41800.)
- (2) Impure hematite. Monroe Furnace. May 11, 1881. (41791.)
- (3) Siderite. Monroe Furnace. May 11, 1881. (41793.)
- (4) Limonite. Near Milton. May 13, 1881. (43666.)
- (5) Impure limonite. Ray's Mine, Byer's Station. May 12, 1881. (41796.)
- (6) Limonite. Swaringen Mine, near Milton. May 13, 1881. (41801.)
- (7) Limonite. Near Milton. May 13, 1881. (41690.)

SCIOTA COUNTY.

- (1) Limonite. Sciota Furnace, near Portsmouth. May 6, 1881. (41836.)
- (2) Limonite. Sciota Furnace, near Portsmouth. May 6, 1881. (41834.)

LAWRENCE COUNTY.

- (1) Impure siderite. Davis Mine, near Jackson. May 10, 1881. (41780.)
- (2) Impure siderite. Hecla Furnace Lands. May 5, 1881. (41766.)
- (3) Limonite. Monroe Furnace. May 7, 1881. (41777.)
- (4) Hematite, kidney ore. Monroe Furnace. May 7, 1881. (41775.)
- (5) Limonite, kidney ore. Washington Furnace. May 11, 1881. (41786.)
- (6) Limonite. Washington Furnace. May 11, 1881. (41785.)

MICHIGAN.

MARQUETTE COUNTY (MARQUETTE DISTRICT.)

- (1) Hematite. Jackson Mine, Negaunee. December 9, 1879. (41580.)
- (2) Hematite. Jackson Mine, Negaunee. December 9, 1879. (41583.)
- (3) Hematite, containing magnetite. Jackson Mine, Negaunee. December 15, 1879. (41579.)
- (4) Hematite, banded. Jackson Mine, Negaunee. December 9, 1879. (41582.)
- (5) Hematite, hard slate ore. Cleveland Mine, Negaunee. December 5, 1879. (41556.)
- (6) Hematite and jasper. Cleveland Mine, Negaunee. December 5, 1879. (41609.)
- (7) Hematite and jasper, banded. New York Mine, Negaunee. December 6, 1879. (41575.)
- (8) Hematite, containing martite or sesquioxide of iron pseudomorph after magnetite. New York Mine, Negaunee. December 6, 1879. (41572.)
- (9) Hematite. New York Mine. December 6, 1879. (41573.)

- (10) Impure hematite. Lake Superior Mine. December 13, 1879. (41604.)
- (11) Hematite. Lake Superior Mine, Negaunee. December 8, 1879. (41605.)
- (12) Hematite. Lake Superior Mine, Negaunee. December 8, 1879. (41607.)
- (13) Limonite. Lake Superior Mine, Negaunee. December 13, 1879. (41600.)
- (14) Hematite. Barnum Mine, Negaunee. December 8, 1879. (41596.)
- (15) Hematite. Barnum Mine, Negaunee. December 6, 1879. (41592.)
- (16) Hematite, in coarse folia. Barnum Mine, Negaunee. December 8, 1879. (41594.)
- (17) Impure magnetite and pyrite. Saginaw Mine, Negaunee. December 11, 1879. (41588.)
- (18) Martite, sesquioxide of iron pseudomorph after magnetite. Saginaw Mine, Negaunee. December 11, 1879. (41587.)

The following specimens are from the Negaunee Range:

- (1) Impure hematite. McComber Mine, Negaunee. December 16, 1879. (41559.)
- (2) Limonite, surface specimen. Cambria Mine, Negaunee. December 13, 1879. (41565.)
- (3) Hematite, specular ore. Republic Mine, Michigamme. December 5, 1879. (41511.)
- (4) Magnetite. Republic Mine, Michigamme. December 5, 1879. (41512.)
- (5) Magnetite. Humboldt Mine, Michigamme. December 12, 1879. (41503.)
- (6) Hematite, specular ore. Champion Mine, Michigamme. December 6, 1879. (41548.)
- (7) Magnetite, crystalline, granular. Champion Mine, Michigamme. December 6, 1879. (41546.)
- (8) Magnetite. Keystone Mine, Michigamme. December 11, 1879. (41553.)
- (9) Magnetite, coarse grained. Keystone Mine, Michigamme. December 11, 1879. (41551.)
- (10) Hematite, coarsely micaceous, as a vein in martite or sesquioxide of iron pseudomorph after magnetite. Michigamme Mine, Michigamme. December 9, 1879. (41517.)
- (11) Impure magnetite. Michigamme Mine, Michigamme. December 9, 1879. (41518.)
- (12) Magnetite. Edwards Mine, Michigamme. December 9, 1879. (41543.)
- (13) Magnetite, crystalline, granular. Edwards Mine. December 9, 1879. (41540.)
- (14) Magnetite. Spur Mountain Mine, Michigamme. December 8, 1879. (41506.)
- (15) Manganese ore. Manganite. Manganese Mine, Negaunee. December 16, 1879. (41563.)

The following specimens represent the Menominee district :

- (1) Hematite. Vulcan Mine. December 17, 1879. (41642.)
- (2) Hematite. Vulcan Mine, Pit No. 1. December 12, 1879. (41650.)
- (3) Hematite. Norway Mine. December 17, 1879. (41631.)
- (4) Hematite, containing calcite. Norway Mine. December 17, 1879. (41638.)
- (5) Hematite. Norway Mine. December 17, 1879. (41639.)
- (6) Hematite. Cyclops Mine. December 2, 1879. (41677.)
- (7) Hematite. Cyclops Mine. December 17, 1879. (41838.)
- (8) Hematite. Quinnesec Mine. December 17, 1879. (41624.)
- (9) Hematite. Quinnesec Mine. December 17, 1879. (41623.)
- (10) Impure hematite. Quinnesec Mine. December 17, 1879. (41619.)
- (11) Hematite. Chapin Mine. December 2, 1879. (41651.)
- (12) Hematite. Emmett Mine. December 17, 1879. (41679.)
- (13) Limonite. Emmett Mine. December 17, 1879. (41678.)
- (14) Hematite. McKenna Mine. December 10, 1879. (41667.)
- (15) Hematite, banded. Saginaw Mine. December 11, 1879. (41612.)

WISCONSIN.

- (1) Martite, sesquioxide of iron pseudomorph after magnetite. Commonwealth Mine, Menomonee. December 15, 1879. (41497.)
- (2) Hematite. Commonwealth Mine, Menomonee. December 15, 1879. (41693.)

JACKSON COUNTY.

- (1) Impure hematite. Blackriver Falls. November 26, 1880. (42092.)

MINNESOTA.

- (1) Hematite. Pit No. 14. Vermillion Lake. October 30, 1880. (43619.)
- (2) Hematite. Vermillion Lake. November 7, 1880. (43614.)
- (3) Hematite. Pit No. 14. Vermillion Lake. October 30, 1880. (43621.)
- (4) Hematite. Vermillion Lake. November 9, 1880. (43623.)
- (5) Hematite. Vermillion Lake. November 7, 1880. (42273.)
- (6) Hematite. Pit No. 3. Vermillion Lake. October 23, 1880. (42265.)
- (7) Hematite. Vermillion Lake. October 22, 1880. (42261.)
- (8) Hematite. Vermillion Lake. October 30, 1880. (41718.)
- (9) Hematite and jasper. Vermillion Lake. November 4, 1880. (41717.)
- (10) Hematite. Vermillion Lake. October 30, 1880. (42267.)
- (11) Hematite. Vermillion Lake. November 30, 1880. (42269.)
- (12) Hematite. Vermillion Lake. November 7, 1880. (42272.)
- (13) Hematite. Vermillion Lake. October 22, 1880. (42263.)

COLORADO.

BOULDER COUNTY.

- (1) Magnetite. Caribou Mine. October 14, 1880. (41840.)
- (2) Impure hematite. Marshall Mine. October 5, 1880. (41839.)

CHAFFEE COUNTY.

- (1) Impure magnetite. Calumet Mine, Calumet. March 3, 1881. (41870.)

COSTILLA COUNTY.

- (1) Magnetite, surface specimen. Ainsworth Mine, near Placer. October 24, 1880. (41842.)

FREMONT COUNTY.

- (1) Magnetite, containing feldspar and quartz. Iron Mountain Mine, near Pine Creek. November 5, 1880. (41848.)
- (2) Magnetite. Iron Mountain Mine, near Pine Creek. November 5, 1880. (41849.)

LAKE COUNTY.

- (1) Limonite. Amie Mine, Leadville. November 15, 1880. (41855.)
- (2) Impure limonite. Amie Mine, Leadville. November 15, 1880. (41860.)
- (3) Limonite. Bruce Mine, Leadville. November 15, 1880. (41859.)

SAGUACHE COUNTY.

- (1) Limonite. Bee Hive Mine. November 12, 1880. (41852.)
- (2) Limonite. Poor Man's Mine. Smith's Gulch. November 12, 1880. (41863.)
- (3) Limonite. Prospect Mine. November 12, 1880. (41867.)

CALIFORNIA.

PLACER COUNTY.

- (1) Magnetite. Clipper Gap Mine. February 2, 1881. (42281.)
- (2) Magnetite. Clipper Gap Mine. February 2, 1881. (42279.)
- (3) Limonite. Clipper Gap Mine. February 2, 1881. (42282.)
- (4) Hematite. Clipper Gap Mine. February 2, 1881. (42280.)

UTAH.

IRON COUNTY.

- (1) Magnetite, showing dodecahedral crystals altered to sesquioxide of iron or martite. Great Western Mine, Iron Springs. December 11, 1880. (43646.)
- (2) Magnetite. Great Western Mine, Iron Springs. December 11, 1880. (42174.)
- (3) Magnetite. Blow Out Mountain Mine. December 14, 1880. (42186.)
- (4) Manganese ore, impure. Adelaide Mine, Iron town. December 13, 1880. (42178.)
- (5) Magnetite. Chesapeake Mine, Iron town. December 13, 1880. (42182.)

BEAVER COUNTY.

- (1) Limonite. Vulcan Mine. December 7, 1880. (42188.)
- (2) Hematite. Frisco Mining Company's Mine. December 7, 1880. (42190.)

JUAB COUNTY.

- (1) Limonite, containing manganese. Billing's Mine. December 21, 1880. (42198.)
- (2) Hematite. Sailor Boy Mine. December 21, 1880. (42196.)

WEBER COUNTY.

- (1) Hematite. Willard Mine, Willard. December 24, 1880. (42171.)

OREGON.

CLACKAMAS COUNTY.

- (1) Magnetite. Prosser Mine, near Oswego. January 12, 1881. (42278.)
- (2) Limonite. Prosser Mine, near Oswego. January 12, 1881. (42277.)
- (3) Limonite. Prosser Mine, near Oswego. January 12, 1881. (43640.)
- (4) Limonite. Patton Mine, near Oswego. January 12, 1881. (42275.)

WASHINGTON.

JEFFERSON COUNTY.

- (1) Limonite. Chimacon Valley Mine. January 15, 1881. (43650.)
- (2) Limonite. Chimacon Valley Mine. January 15, 1881. (43652.)

THE EXTRACTION OF IRON.

Iron is placed upon the market in three distinct and characteristic forms, depending for the most part upon the amount and condition of the carbon in the metal. First, wrought iron, which contains little or no carbon, and the best varieties only trifling amounts of impurities, it may, however, contain considerable phosphorus, and when badly manufactured, may contain considerable mechanically inclosed slag. Second, steel, containing from two-tenths to $1\frac{1}{2}$ per cent. of carbon, with only trifling amounts of impurities. Third, pig iron, containing from $2\frac{1}{2}$ to 5 or more per cent. of carbon, both free and combined, together with

silicon and manganese, and, when made from impure ores, phosphorus and sulphur, besides small amounts of other impurities.

THE MANUFACTURE OF WROUGHT IRON.

A small amount of wrought iron is manufactured direct from the ore, mostly by the old Catalan process. In this process a rectangular furnace provided with suitable tuyeres is charged alternately with fine ore and charcoal. The charcoal reduces a portion of the iron to the metallic state in particles, and these particles stick to each other, and gather into a lump, while the remainder of the iron with the impurities of the ore form a slag, and settle to the bottom, from whence it is drawn off by a suitable opening. When a sufficient amount of iron has accumulated to form a "loupe" it is removed from the fire, and hammered down to a bar, which is then ready for use. This process is very wasteful of the iron, and is only practiced in remote regions except where, as in Northern New York, a considerable amount of very pure ore is obtainable that can not readily be treated by any other process. The product from these pure ores is very high grade.

By far the largest amount of wrought iron is manufactured by the puddling process. For this purpose the iron of the ores is first made into pig iron in a blast furnace, and is then treated in a reverberatory furnace to remove the impurities. The product of this operation depends upon the quality of the ore used in the blast furnace, and the care and skill of the workman in puddling.

ROGERSFIELD MINE OF THE CHATEAUGAY ORE AND IRON COMPANY.

This deposit, consisting of a mixture of magnetite, with feldspar, hornblende, and quartz, is inclosed in gneiss. Its course is NE. and SW., and has been traced for 12 miles. At a depth of 600 feet it is 18 feet wide. It is quite free from faults, although intercepted by thin dikes. In mining, all the material between the vein walls is extracted, leaving only sufficient pillars to support the roof, and the space between is empty, as shown on PL. XI.

In 1884 15,000 tons of rich furnace ore was extracted, of the following composition:

	Per cent.
Magnetic oxide of iron (Fe_3O_4)	70.592
Alumina (Al_2O_3)	1.283
Lime (CaO)	4.260
Magnesia (MgO)	2.112
Manganese (Mn)	traces
Silica (SiO_2)	19.260
Phosphoric acid (P_2O_5)	0.031
Sulphur (S)	0.088
Water (H_2O)	1.080
Also small quantities of carbonic acid, alkalies, etc.	
Metallic iron (Fe)	51.118
Phosphorus (P)	0.013

Analysts. Booth, Garrett and Blair.



ROGERSFIELD IRON MINE.
(See explanation, page XIV.)

J. Moss [illegible]

Besides this, about 3,000 tons of second-quality ore were mined. This second-quality ore is roasted in rectangular kilns, in charges of 100 tons, for which 35 cords of wood are required. The complete roasting requires 5 days, but as soon as the front of the charge is roasted it is removed, and successive portions are taken out from time to time until the charge is completed. This roasting is mainly for the purpose of disintegrating the ore previous to stamping. The roasted ore is subjected to coarse crushing, dry, to pass through screens with holes three-eighths of an inch in diameter. The crushed material is concentrated on a Conkling jig. Two tons of this concentrating ore will furnish about 1 ton of concentrates containing 60 to 65 per cent. of iron.

The furnace ore is shipped away for smelting and the concentrates are treated in the Belmont forge by the Catalan process. The collection taken by Mr. J. B. Mackintosh, E. M., August, 1884, shows:

Ore.

- (1) Furnace. Magnetite, granular, in thin layers. (54209.)
- (2) Concentrating. Magnetite, feldspar, hornblende, and quartz. (54208.)
- (3) Roasted. (54210.)
- (4) Concentrates. (54211.)

Tailings.

- (1) Containing the quartz, feldspar, hornblende, with a little magnetite, of the ore. From the concentrating operation. (54212.)

BELMONT FORGE.

This forge is situated at the northern end of Chateaugay Lake, Franklin County, New York, and the power for running it is furnished by the Chateaugay River. The ore used is the separated ore from the Rogersfield mine, which still contains sufficient of the original gangue material to form all the slag required, so that no flux is used. The fuel is charcoal. The variety of wood used for this purpose includes birch, maple, tamarack, cherry, elm, beech, hemlock, pine, poplar, spruce, balsam, ash, and basswood, the harder wood producing the best charcoal. The wood yields from 42 to 45 bushels of charcoal per cord. The forge contains sixteen fires, consisting of a fireplace surmounted by a rectangular chimney $7\frac{1}{2}$ by $4\frac{1}{2}$ feet. The fireplace is 3 feet 6 inches wide and 3 feet deep, with a working plate projecting 2 feet 6 inches in front. All the work is carried on through one opening 3 feet 6 inches by 2 feet. The lower first foot of the front is closed by the cinder plate, through which the cinder is tapped from several holes. Pipes for heating the blast previous to its use are arranged in the upper part of the chimney.

This fireplace is first charged with sufficient charcoal to bring it to a proper temperature, and charges of ore and charcoal are then added successively. A portion of the iron is reduced to the metallic state, and these particles gather together until a suitable lump called "loupe"

has accumulated. About three hours are required to produce the proper sized loupe. This loupe is taken out of the fire and into the hole left a suitable amount of ore is thrown and the process of reduction continued. The loupe is taken to the hammer and is hammered to consolidate the iron and expel the slag. One end is finished to 7 inches square, and the other end is put back into the furnace to heat it up again, which does not interfere with the operation of the furnace. When the bloom is hot enough it is taken back to the hammer and the other end finished to 7 inches. In some cases this 7-inch bloom is reduced to $3\frac{1}{2}$ -inch billets.

A good workman will produce a ton of blooms with 250 to 260 bushels of charcoal, and a ton of billets with 312 bushels, but these figures are often exceeded.

A general interior view of the forge is shown in PL. XII the trip hammer in PL. XIII, and a general collection of tools used in PL. XIV.

During the smelting operation two characters of slag are produced, depending upon the temperature of the fire. When the fire is hot the slag is very vesicular and gives off jets of gas. When, however, it is cold, the slag flows quietly and is compact. There are formed also two by-products. One, known as coal crust, consists of a mixture of infusible slags, iron, and coal, and gathers on the top of the slag. The other, known as emery, consists of fine material carried forward by the blast and collected in the chimney.

The collection joins the Rogersfield Mine collection, which supplies the ores, and was also taken by Mr. J. B. Mackintosh, E. M., August, 1884.

- (1) Wood, maple; used for making charcoal. (54191.)
- (2) Charcoal, used for fuel. (54192.)
- (3) Iron, a test button taken from the furnace to observe its workings. (54190.)
- (4) Cinder, from hot furnace. (54186.)
- (5) Cinder, from cold furnace. (54187.)
- (6) Cinder, squeezed from the bloom in hammering. (54189.)
- (7) Scale, produced in hammering the reheated bloom. (54188.)
- (8) Coal crust. (54184.)
- (9) Emery. (54185.)

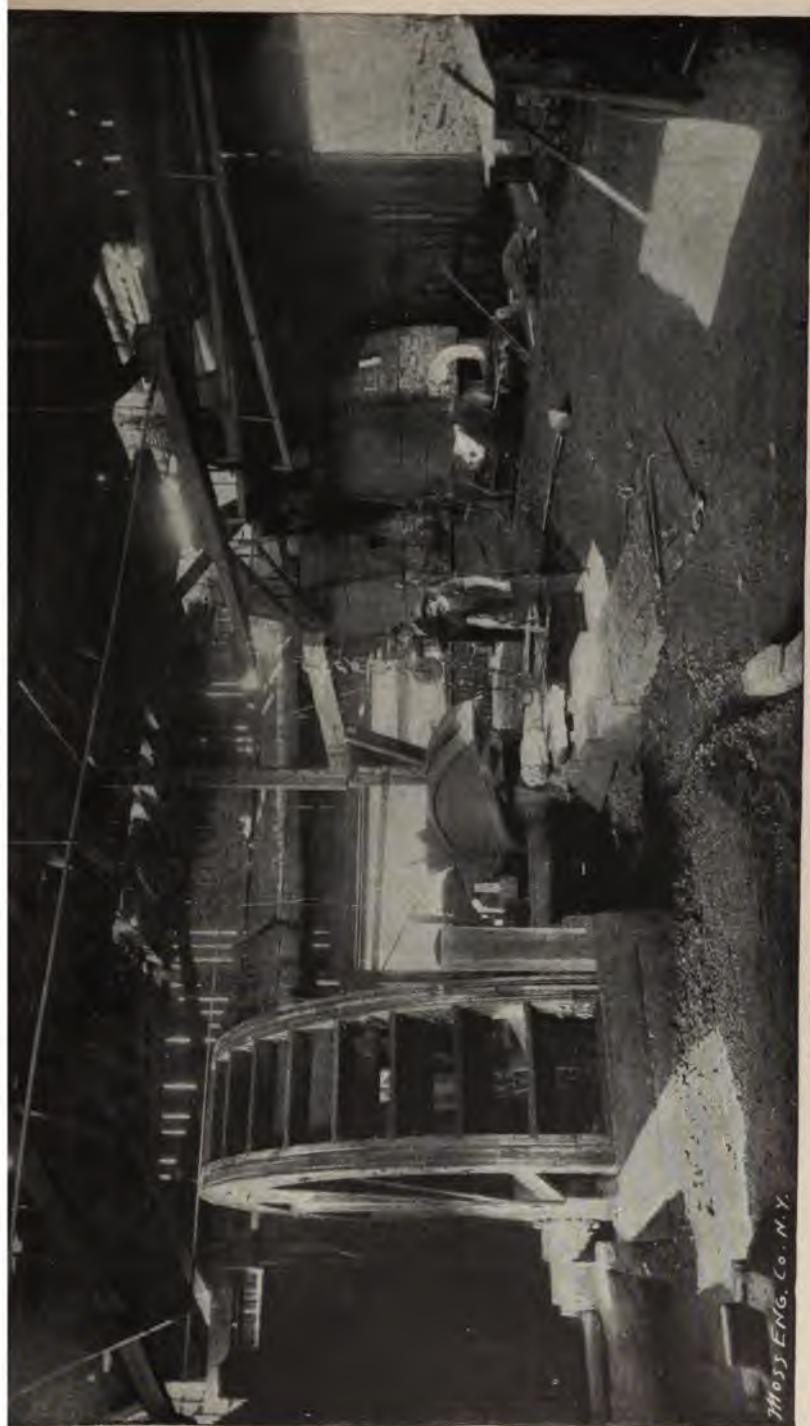
THE MANUFACTURE OF STEEL.

A small amount of steel is made direct from the ore, but, as in the case of wrought iron, nearly all is made from pig-iron that has been reduced in a blast furnace.

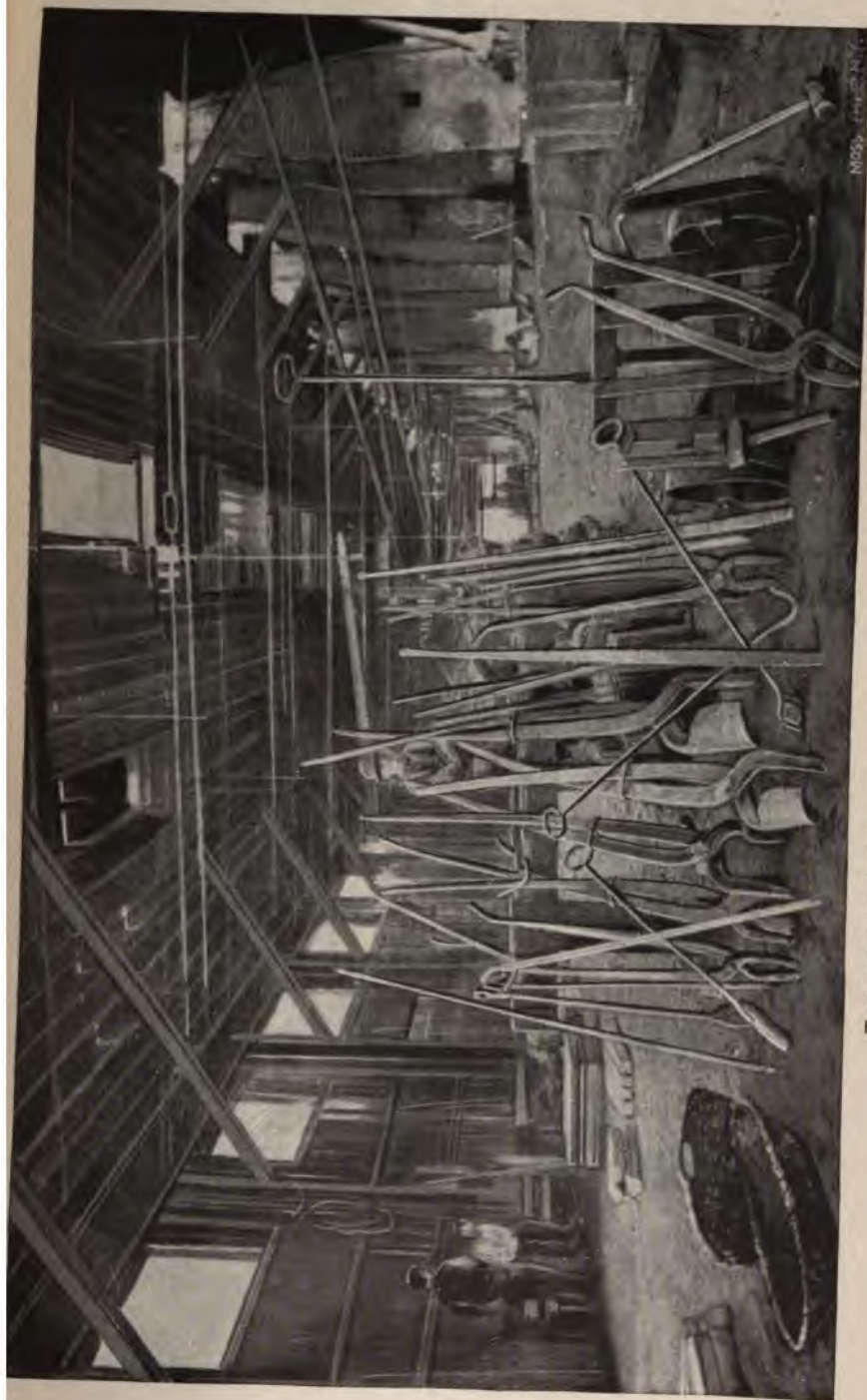
Since the main difference between pig-iron and steel lies in the different percentages of carbon they contain, the process of steelmaking should simply be the removal of the proper amount of carbon from pig-iron containing only small amounts of impurities, and this is sometimes the case, but it is far more frequent to remove as much as possible of the carbon and then to add just the right amount, this being easier than to remove just the right amount at once.



INTERIOR OF BELMONT FORGE, CHATEAUGAY LAKE, NEW YORK.
(See explanation, page XIV.)



TRIP HAMMER AT BELMONT FORGE, CHATEAUGAY LAKE, NEW YORK.
* (See explanation, page XIV.)



TOOLS USED AT BELMONT FORGE, CHATEAUGAY LAKE, NEW YORK.
(See explanation, page XIV.)

In many cases the total removal of the carbon has another advantage, in that at the same time impurities are removed from the metal, and thus a lower grade of pig-iron can be utilized.

THE CEMENTATION STEEL PROCESS.

In this process bars of puddled iron are first exposed to a temperature of about $1,100^{\circ}\text{C}$. after being packed in iron boxes with charcoal. By this operation the carbon of the charcoal enters the bar-iron and gradually changes it to steel.

The time required depends upon the grade of steel to be produced or the amount of carbon the steel must contain. An ordinary charge of 12 to 18 tons will be converted into spring steel in about 7 days and will contain about one-half per cent. of carbon, while the highest grade or melting heat steel requires 9 to 10 days and will contain $1\frac{1}{2}$ per cent. of carbon. When the conversion is completed the furnace is cooled and the bars removed.

The smooth bars of wrought iron will now be found covered with blisters, and this material is frequently called blister steel. The character of the blisters indicates the quality of the steel, but the quality of a charge is never uniform through the whole mass.

The blister bars are now broken and sorted according to fracture. Sometimes these pieces are piled or fagoted and rolled directly to bar steel, but this treatment alters the grade of the metal, and, owing to the lack of uniformity in the blister steel, the product is not at all uniform, so that it is more common to cut the bars of blistered steel into small pieces, charge them into crucibles with certain additions, especially manganese ore and ferromanganese, to improve the quality, and then to melt them.

The melted steel is cast into ingots and is then ordinary cast-steel. Cast-steel is, however, frequently produced by other processes; the word "cast" simply means that the steel has been melted.

This process is illustrated by a collection from the Crescent Steel Works of Miller, Metcalf & Parkin, Pittsburg, Pennsylvania.

- (1) Pig-iron, used for making puddled bar-iron. (54400.)
- (2) Puddled bar-iron, used for conversion into blister steel in cementing ovens. (54401.)
- (3) Cinder, produced in making puddled bar-iron. (54402.)
- (4) Cinder, hammered from the puddled ball in making puddled bar. (54403.)
- (5) Blister steel, after passing through the cementing furnace. (54404.)
- (6) Charcoal, used to impart carbon to the metal in the conversion of bar-iron into steel in the cementing furnace. (54405.)
- (7) Cast-steel, a piece of ingot as cast from the melting pot. (54408.)
- (8) Manganese ore, used in the crucible when melting blister steel. (54406.)
- (9) Ferromanganese, an alloy of iron and manganese used in the crucible when melting blister steel. (54407.)
- (10) Cinder, produced in melting blister steel in crucibles. (54409.)
- (11) Crucible steel, an ingot of cast steel which has been heated and hammered to close up gas bubbles (blowholes), sometimes called welding. (54410.)

- (12) Clay, used to slag off oxide of iron and to protect the metal during welding. (54411.)
- (13) Hammer scale, formed during the welding from the clay and oxide of iron. (54412.)
- (14) Crucible steel, finished bar; made by heating and hammering the welded bar. (54413.)
- (15) Hammer scale, produced by the oxidation of the metal while being hammered. (54414.)
- (16) Crucible steel, cold-rolled bar for drill rods, annealed. (54415.)
- (17) Crucible steel, cold-rolled bar for drill rods, finished. (54416.)
- (18) Crucible steel, cold-rolled plate for rough stock. (54417.)
- (19) Crucible steel, cold-rolled plate, finished sheet. (54418.)
- (20) Crucible steel, sheet .004 inch thick. (54970.)

THE CINCINNATI STEEL WORKS.

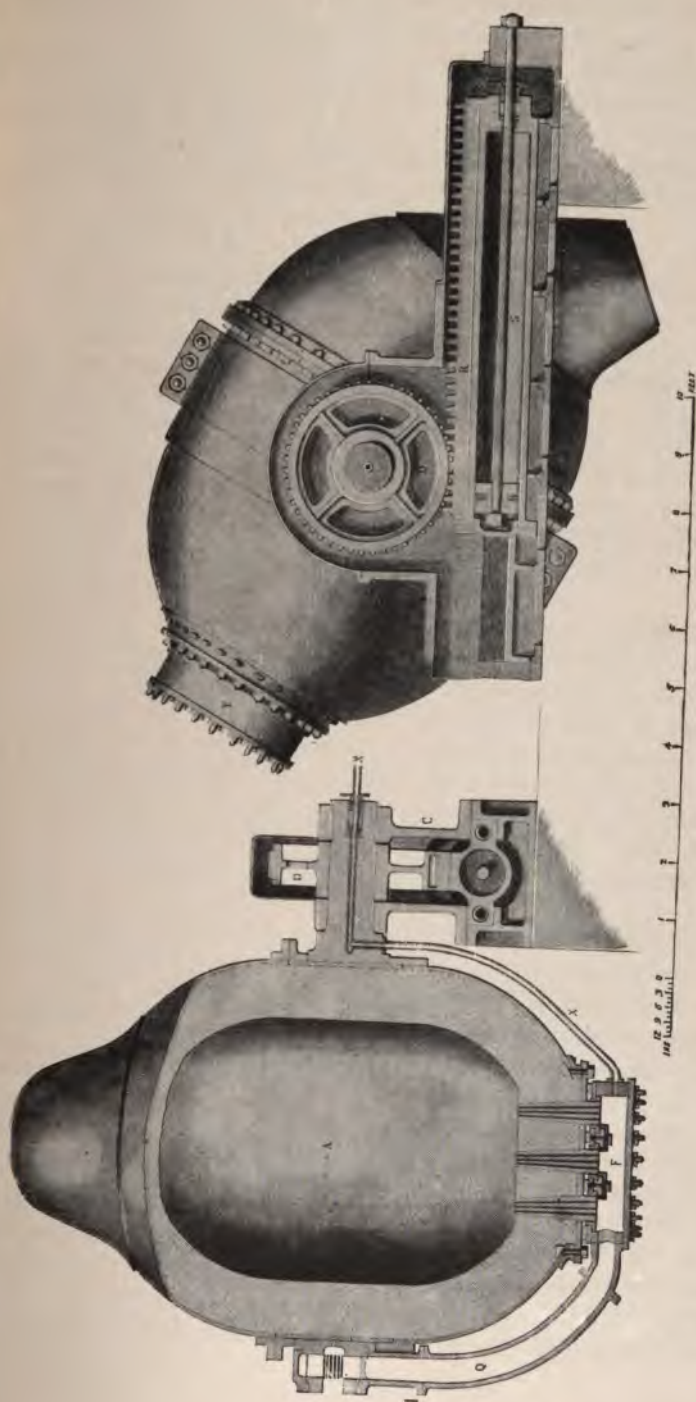
As being of historical interest three specimens of the first crucible steel made in America, together with a wood engraving of the works, are shown here. These works were built in 1832 near Cincinnati on the Miami Canal, and the first steel was made in August of the same year. The proprietors were Garrard Brothers, of whom Dr. Wm. Garrard is still living at Fallston, Pennsylvania. (51130, 51131, 51132, and 51133.)

THE BESSEMER STEEL PROCESS.

This process consists in blowing air through a bath of melted pig-iron, whereby the silicon, carbon, most of the manganese, and a little of the iron are oxidized, the heat furnished by their oxidation being sufficient to keep the metal fluid, both during the process and also for the time necessary after its close to finish and cast the steel.

The conversion takes place in a vessel called a converter, the body of which is egg shaped, with a suitable neck on top inclined about 30 degrees to the body, and a flat bottom with a number of openings for the tuyeres through which the air is blown. Around the middle of the converter is a heavy band carrying the trunnions on which it is supported and swings. The trunnion on one side is solid, and has a geared wheel by which the converter is rotated. The trunnion on the other side is hollow, and serves for the introduction of the blast. After passing through the trunnion, the blast is delivered to a tuyere box below the bottom, into which the tuyeres open. The tuyeres vary in number from 10 to 15, are made of refractory material, and each tuyere is perforated by ten to twelve small holes. The converters are made with a shell of iron from three-quarters to 1 inch thick, lined with 10 to 12 inches of fire brick, and hold from 6 to 15 tons of metal.

The action of the process is as follows: The converter lining being in good condition and the converter hot enough, it is turned down on its side, and the charge of melted pig-iron run in. In this position the metal is held entirely below the line of tuyeres, and the blast is therefore turned off, but as soon as all the charge is in, the vessel is brought back to the



BESSEMER CONVERTER.
(See explanation, page XV.)

upright position, and at the same time the blast, under a pressure of 20 to 30 pounds, is turned on in order to keep the metal from flowing into the tuyeres. Immediately the silicon of the pig-iron oxidizes, and, as a result, the graphitic carbon of the pig-iron is changed to combined carbon. In from 3 to 5 minutes most of the silicon has been oxidized to silica, which unites with the oxides of iron and manganese formed at the same time, producing a slag. This is known as the first period, and is characterized by a short feeble flame, with an abundant shower of sparks from the throat of the converter, and a peculiar roar; towards the end of the period the flame grows longer, the sparks finer and less abundant, and the second period begins, in which the flame grows much longer, and a large amount of carbon is oxidized, while there is a remarkable change in the sound from the throat of the converter. This period lasts from 4 to 10 minutes, and corresponds to the boiling period in the puddling process; it gradually merges into the third period, in which the roar increases, while the flame diminishes, but grows very bright; this continues from 3 to 5 minutes, when the flame and sounds almost entirely cease, and the decarburizing is complete. At this point the converter must be turned down and the blast of air turned off, or the iron will be rapidly oxidized and considerable loss incurred, while the quality of the metal may be completely ruined.

A certain amount of an alloy of iron and manganese, spiegeleisen, or the richer ferromanganese, high in carbon, is now added to the converter in order to introduce the necessary amount of carbon to give the grade of steel required, and also to insure sounder castings by the introduction of the manganese. Formerly it was the practice to turn the converter up again and continue the blow for a few seconds, but now the charge is allowed to stand a few moments for the proper mixing of the spiegel with the iron and the separation of the slag. The charge has now been converted into steel, and the process has taken from 10 to 20 minutes.

Instead of burning out all the carbon and then adding it again in the spiegel, the decarburizing might be stopped just at the point when the carbon has reached the right percentage, and this was formerly done, especially at some Swedish works, but it has been found more practicable to burn out all the carbon possible, and then add the required amount.

The steel is now poured into a ladle. The converter is repaired, if necessary, and is then ready for a new charge, while the steel in the ladle is cast into ingots. The ingots are removed as soon as they have solidified and taken to the rolling mill, where they are rolled into rails.

The handling of such masses of metal requires very powerful hydraulic machinery, but this, as well as the blast, is all controlled by one man, who stands on a platform in a commanding position, and by the movement of a few levers, conveniently placed to his hands, directs and controls the whole process.

A Bessemer works generally contains a pair of converters, and in the best works about thirty blows are made during the 24 hours.

This process requires certain characteristics in the pig-iron to be used. In general it should contain about 2 per cent. of silicon in order to give the necessary heat, by its combustion, to the bath of metal to keep it fluid. It should contain from 3 to 5 per cent. of carbon, and about 1 per cent. of manganese is desirable. Since all the phosphorus and sulphur present in the pig-iron is found in the steel, and since they injure the quality of the metal, it is absolutely necessary that they should be kept very low in the pig, one-tenth of 1 per cent. being the limit for phosphorus, while the sulphur is generally kept below half that amount.

The converter lining, especially on the bottom, requires frequent repairs, since it is subject to high temperature, to violent mechanical motion, and to destructive chemical action. The bottom is therefore made separate, and has to be removed on the average after from eight to ten blows, while from three to four sets of tuyeres are burned out every 24 hours. For this reason much more time is taken up in the repairs than in the actual process of conversion.

The pig-iron is sometimes melted in auxiliary cupola furnaces, while at others it is taken direct from the blast furnace to the converter. The spiegel is melted in a cupola, tapped out into a ladle, and weighed, so as to introduce the exact amount required.

The casting ladle is hung on an hydraulic crane, which swings around in a circle over the molds in which the ingots are cast.

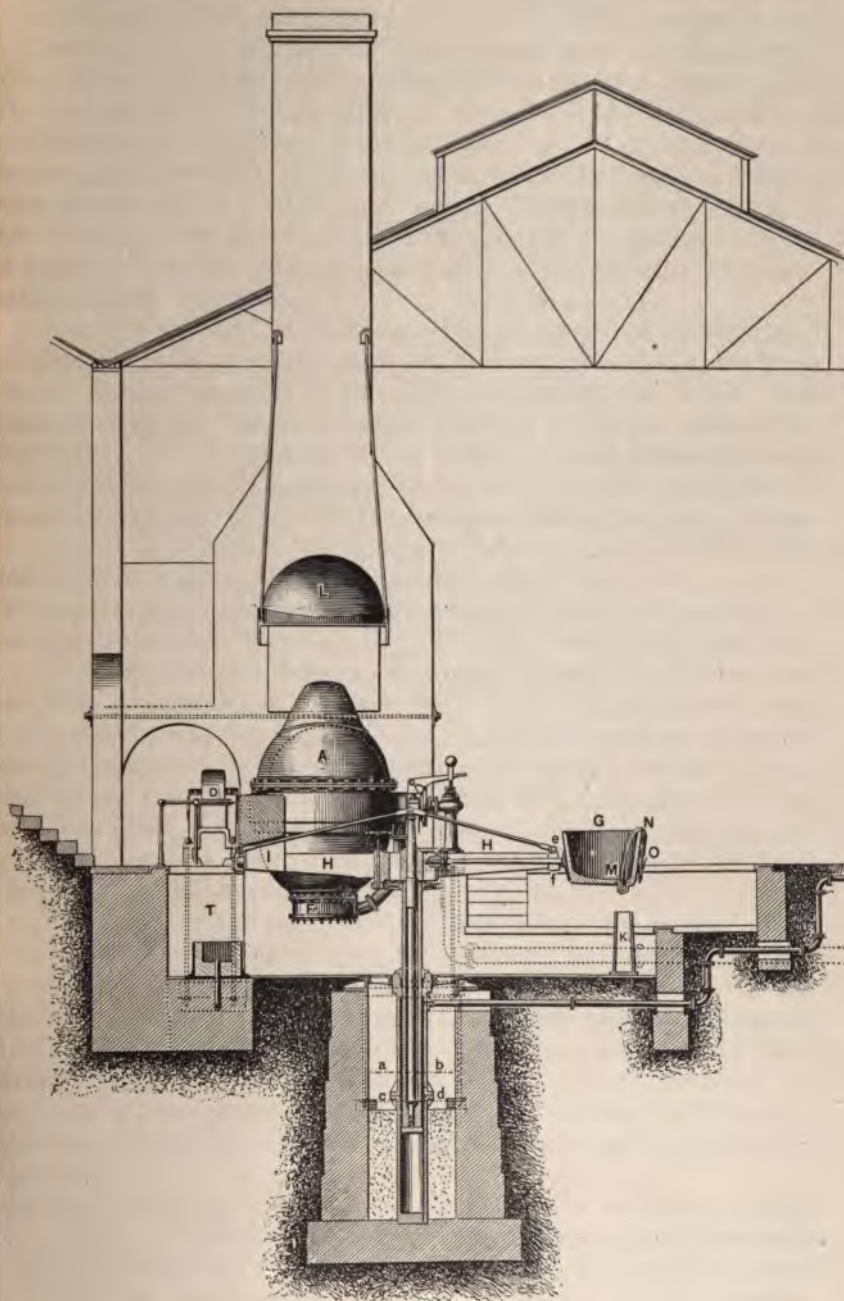
The Bessemer process is eminently fitted for the production of large amounts of steel at a very low cost. Formerly its use was almost entirely limited to the manufacture of steel rails, but it is now being used largely for other purposes.

The construction of the converter is shown in PL. XV, and the general arrangement of the steel house in PL. XVI.

THE SOUTH CHICAGO BESSEMER WORKS.

These works are situated 12 miles from Chicago, on the north side of Calumet River, at its mouth. They have a frontage of 2,500 feet on the lake, 2,400 feet on the Calumet River, and a slip for vessels 1,000 feet long. There are also 11 miles of railroad track for the handling of material, and connecting the works with six trunk lines of railroad. Thus they have most ample means for getting supplies and shipping product. They cover 85 acres. The plant comprises four blast furnaces, three 10-ton converters, and a rail mill where the ingots can be rolled in a single heat. Each department is thoroughly equipped with the most modern machinery.

The ores smelted in the blast furnaces are obtained mostly from the Lake Superior regions, and frequently as many as twelve different varieties are used in a single charge. This mixture is made up in



INTERIOR OF BESSEMER STEEL HOUSE.
(See explanation, page XV.)

rounds, consisting of one barrow of each of the different ores, and the requisite number of coke and limestone. The charge descends uniformly in the furnace, and from 18 to 20 hours elapse between charging the ore at the top and tapping the metal from the same ore at the bottom. The furnaces are tapped six times in 24 hours, about 30 tons of iron and 33 tons of slag being taken at each tap. While the metal is being tapped a sample is taken out and cast in a chill mold, in order to guide the steel blower in the conversion. There are nine grades of iron recognized, which are the ordinary grades of one to three divided by fourths. The iron generally contains about $1\frac{1}{2}$ per cent. of silicon, and $3\frac{1}{2}$ per cent. of carbon.

The pig-iron from the blast furnace is tapped into ladles holding about 10 tons of metal, and carried direct to the converter. It takes from one-half to three-quarters of an hour to transport the metal. One charge was successfully blown after standing 14 hours. During the time the pig iron is standing in the ladle there is a constant separation of graphite from the metal going on, and samples taken just before pouring into the converter always show a marked tendency towards white iron. A little over 1 per cent. of the iron remains in the ladle in the form of a skull, which is periodically removed.

The converter is constructed with a removable shell, and is hung on cast-iron trunnions. The body is cylindrical, 10 feet in diameter and $11\frac{1}{2}$ feet long, and the bottoms, of which 15 are supplied for each converter, are somewhat hollowed out. There are 18 tuyeres, each having twelve three-fourths-inch holes. The converters are arranged in a row, and discharge their steel into ladles upon receiving cranes, which deliver the ladles to the casting crane from which the ingots are cast. The ingot molds are arranged in pairs, and four pairs are generally used for each blow. The height to which the molds are filled is governed by the weight of the rail to be made.

At the beginning and end of the cast a sample of the steel is cast in a small ingot, and subjected to tests to determine its quality. For this purpose they are drawn out to a bar 1 inch square, under a steam hammer. One end of this bar is drawn to a rod one-quarter inch square. The 1-inch bar is nicked while hot, and broken when cold to show the fracture, and the quarter-inch rod is bent cold on the anvil. A sharp bend at right angles without showing any tendency to fracture is considered satisfactory, but in many cases they are doubled flat without breaking.

As soon as the ingots are cold enough the molds are lifted off from them and they are taken to the rail mill, where they are rolled into rails in a single heat, each ingot making four rails. The steel made is of excellent quality as shown by the mechanical tests, and its composition is kept very uniform, containing about 0.034 per cent. silicon, 0.112 to 0.118 per cent. phosphorus, 1.20 to 1.24 per cent. manganese, 0.35 to 0.4 per cent. of carbon, and 0.025 per cent. sulphur.

The blast furnaces have a capacity of producing iron enough for 2,300 tons of rails per week, but the capacity of the steel and rolling mills is greater, and by the addition of cupolas for independent remelting of pig-iron the product can be brought up to 4,000 tons of rails.

The collection was made by E. B. Kirby, E. M., and E. L. Zukoski, E. M., in September, 1884.

A large series of the ores smelted in blast furnace No. 5, nearly all of which are from the Lake Superior mines, together with the fluxes and fuels, were taken September 9, 1884, and on the following day at 2 o'clock, when the metal was cast from the charges they represent, a ladleful was selected and followed through the whole process, to the rolling of the rail, and samples taken to represent each step. The action of the blast furnace was regular and normal, and the pig-iron smelted of the usual grade, and the operations throughout represent the regular work of the plant. To these are added some general specimens illustrating the process, together with a large series of the refractory materials used.

The charge in the blast furnace for several weeks previous to taking the samples was:

	Pounds.
12 barrows coke, each 525 pounds.....	6,300
6 barrows limestone, each 525 pounds.....	3,150
1 barrow Angeline Hematite.....	700
1 barrow Barnum.....	800
1 barrow Cambria.....	900
1 barrow Chapin.....	900
1 barrow Cleveland, specular.....	900
1 barrow Cleveland, hematite.....	900
1 barrow Ludington.....	800
1 barrow Michigamme.....	700
2 barrows Pilot Knob, each 800 pounds.....	1,600
2 barrows Summit, each 800 pounds.....	1,600
Converter spittings.....	223
Steel scrap.....	84
Old ingot molds.....	377
Total.....	19,934

Fifty-nine rounds of the above charge were introduced on the day the samples were taken, making 371,700 pounds of fuel and 804,406 pounds of ore, flux, etc., charged.

BLAST FURNACE SPECIMENS.

Ore.

- (1) Hematite. Cleveland Mine, Marquette County, Michigan. (54803.)
- (2) Hematite. Cleveland Mine, Marquette County, Michigan. (54793.)
- (3) Hematite. Angeline Mine, Marquette County, Michigan. (54798.)
- (4) Hematite. Barnum Mine, Marquette County, Michigan. (54799.)
- (5) Hematite. Cambria Mine, Marquette County, Michigan. (54794.)
- (6) Magnetite. Michigamme Mine, Marquette County, Michigan. (54801.)

- (7) Magnetite and hornblende. Michigamme Mine, Marquette County, Michigan. (54800.)
- (8) Hematite. Chapin Mine, Menominee County, Michigan. (54796.)
- (9) Hematite. Chapin Mine, Menominee County, Michigan. (54795.)
- (10) Hematite. Ludington Mine, Menominee County, Michigan. (54797.)
- (11) Hematite. Summit Mine, Ontonagon County, Michigan. (54792.)
- (12) Hematite. Pilot Knob Mine, Iron County, Missouri. (54802.)

Flux.

- (1) Limestone. Chicago, Cook County, Illinois. (54784.)

Fuel.

- (1) Coke. Connellsville, Pennsylvania. (54770.)

Products.

- (1) Slag, from previous tap of metal. (45753.)
- (2) Slag, first flush, 12.45 p. m. (54752.)
- (3) Slag, second flush; just before tapping metal, 1.40 p. m. (54754.)
- (4) Pig-iron, from beginning of tap, 2.09 p. m. Grade 1 $\frac{1}{4}$. (54818.)
- (5) Pig-iron, chill sample from beginning of tap. (54821.)
- (6) Slag, skimmed from the iron while tapping, 2.15 p. m. (54755.)
- (7) Pig-iron, from end of tap, 2.20 p. m. Grade, 1 $\frac{1}{4}$. (54819.)
- (8) Pig-iron, chilled sample from end of tap. (54826.)

STEEL HOUSE SPECIMENS.

The second ladle of heat 19 of the blast furnace was selected to follow through the process as "blow No. 13391." The metal weighed 22,400 pounds. The record of the blow is as follows:

1,000 pounds of scrap-iron were charged into the converter, and at—

3.03 $\frac{1}{2}$ p. m. the pig-iron was poured.

3.04 p. m. converter turned and blast let on.

3.07 p. m. second period began.

3.10 p. m. third period began.

3.12 $\frac{1}{2}$ p. m. end of blow.

3.13 $\frac{1}{2}$ p. m. converter turned down and blast shut off; length of blow 9 $\frac{1}{2}$ minutes; blast varied from 18 to 20 pounds.

3.16 p. m. 1,200 pounds of spiegel added.

3.16 $\frac{1}{2}$ p. m. steel poured into ladle.

3.19 p. m. first ingot cast.

3.23 p. m. eighth ingot cast.

3.34 p. m. molds stripped from ingots.

3.48 $\frac{1}{2}$ p. m. eighth ingot loaded on car. All were then taken to the scales.

(1) Pig-iron, chill sample, taken as the metal flowed from the blast furnace into the second ladle. 2.15 p. m. (54786.)

(2) Pig-iron, chill sample, taken as the metal was poured from the ladle into the converter 39 minutes after. (54824.)

(3) Graphite skull, taken from the bottom of the hot metal ladle. (54747.)

(4) Converter spittings, consisting of globules of metal and slag thrown from the mouth of the converter by the force of the blast during the conversion of the pig-iron into steel. (54760.)

(5) Steel slag, formed in the converter during the conversion of pig-iron into steel; sample taken from under the converter. (54750.)

- (6) Steel slag, formed in the converter during the conversion of pig-iron into steel; sample taken from under the converter, showing some metal. (54751.)
- (7) Spiegeleisen, an alloy of iron and manganese rich in carbon; used to recarburize the bath of metal at the end of the blow. (54829.)
- (8) Spiegeleisen, an alloy of iron and manganese rich in carbon; used to recarburize the bath of metal at the end of the blow. (54827.)
- (9) Spiegeleisen, average sample before melting. (54830.)
- (10) Spiegeleisen, after melting. (54820.)
- (11) Coke, from Connellsville, Pennsylvania; used to melt spiegeleisen in cupola. (54769.)
- (12) Limestone, used in melting spiegeleisen in cupola. (54779.)
- (13) Spiegeleisen slag, from the cupola. (54756.)
- (14) Steel, test ingot; taken from beginning of the cast. (54823.)
- (15) Steel, test ingot; drawn down under the steam hammer to one-fourth inch square and then coiled cold. (54831.)
- (16) Steel, test ingot; drawn down under the steam hammer and then coiled cold. (54832.)
- (17) Steel slag, taken from the casting ladle after the metal had been tapped. (54761.)

RAIL-MILL SAMPLES.

The record is continued in the rail mill as follows:

- 3.51½ p. m., first ingot in reheating furnace.
- 4.35 p. m., first ingot out of reheating furnace sent to blooming train.
- 4.37½ p. m., bloom enters the rolls of the rail mill after having gone through 15 passes in the blooming train.
- 4.39½ p. m., rails leave the rolls, having gone through 7 passes in the rail train.
- 4.40½ p. m., first pair of rails deposited at the end of cooling table, 2 hours and 23 minutes after the metal was tapped from the blast furnace.
- (1) Reheating cinder, from the Siemens gas furnace for reheating. (54762.)
- (2) Roller scale, from rail-mill rolls. (54758.)
- (3) Roller scale, from rail-mill rolls. (54759.)
- (4) Rail, fag end of rail. (54815.)
- (5) Rail section, taken from the middle of a 120-foot length. (54816.)

GENERAL ILLUSTRATIONS OF THE PROCESS.

- (1) Pig-iron, cast in a chill, showing grade No. 2½. (54825.)
- (2) Salamander, taken from the bottom of the blast furnace on blowing out. (54757.)
- (3) Graphite, taken from the bottom of the blast furnace on blowing out. (54746.)
- (4) Test ingot, drawn under the steam hammer to one-fourth inch square and bent double cold, the regular test made of every blow. (54833.)
- (5) Steel slag, formed in the converter during the blow; representative sample. (54749.)
- (6) Indiana block coal, used under the boilers of the steel house and mill. (54780.)
- (7) Nut coal, washed, from Streator, Illinois; used in the Siemens gas producers. (54781.)
- (8) Nut coal, washed, from Streator, Illinois; used in the Siemens gas producers and at the mill. (54834.)

REFRACTORY MATERIALS.

- (1) Benezette fire brick, used in lining the blast furnace up to the top of the bosh. (54790.)
- (2) Clarion fire brick, used in lining the blast furnace, from the top of the bosh for 29 feet. (54766.)

- (3) No. 2 fire brick, used in lining the blast furnace, from 29 feet above bosh to the top of the stack. (54777.)
- (4) Prepared Portsmouth clay, used for mortar in lining the blast furnace. It has been boiled and mixed with one-half its weight of ground old fire brick. (54835.)
- (5) Prepared Utica clay, used in building blast furnaces. (54776.)
- (6) Blue clay, from Wilmington, Illinois, used for closing the tap holes and other purposes about the furnaces. (54764.)
- (7) Fire brick, taken from bosh of the blast furnace after being in use. (54785.)
- (8) Fire brick, taken from the walls of the blast furnace after being in use. (54748.)
- (9) Ganister, Lake Superior quartzite; used for lining the converter. (54783.)
- (10) Crushed ganister, used in making refractory mixture for lining the converter. (54774.)
- (11) Fire clay, from Streator, Illinois; used in making refractory mixture for lining converter. (54767.)
- (12) Fire clay, crushed, from Streator, Illinois; used in making refractory mixture for lining converter. (54773.)
- (13) Quartz sand, from Utica, Illinois; used in making refractory mixture for lining converter. (54775.)
- (14) Ball stuff, made from crushed ganister, fire clay, and sand; used for lining the converter. (54778.)
- (15) Old fire brick, used in making refractory mixture for lining the bottoms of converters. (54765.)
- (16) Fire brick, crushed; used in making refractory mixture for lining the bottoms of converters. (54772.)
- (17) Lining material, made of crushed ganister, sand, and fire brick; used for lining the bottoms of converters. (54763.)
- (18) Joint stuff, used for making the joint between the vessel and its bottom; made of loam, ganister, and fire clay. (54789.)
- (19) Tuyere, used for the introduction of the air into the molten metal. (54791.)
- (20) Hydraulic cement, used for fastening the tuyeres into the bottom of the converter; made of Portland cement and clay. (54787.)
- (21) Loam, from Joliet, Illinois; used for lining steel and hot-metal ladles. (54768.)
- (22) Stopper, used to close the vent of the casting ladle. (54788.)

THE SMELTING OF PIG-IRON.

For this purpose iron ores are mixed with suitable fluxes and with the necessary fuel and the whole charged into shaft furnaces into which air is blown for the combustion of the fuel to furnish the heat necessary for the operation.

The shaft furnaces are circular in section and vary greatly in diameter and also in height, according to the amount of metal they are to produce. Small old-fashioned charcoal furnaces produce from 3 to 4 tons per day, while a few modern coke furnaces have produced 300 tons in a day. The diameter varies at different heights in the same furnace, and the adjustment of this diameter is very important, since it is one of the chief factors in determining the success of the furnace. At the bottom of the furnace are openings for drawing off the metal and slag, and just above these are other openings for the tuyeres for the introduction of the air. The top of the furnace is kept closed in most modern furnaces, except when material is being introduced, and

just below the top are openings for drawing off the hot gases, which are used for various purposes about the furnace.

The general arrangement and construction of a typical blast furnace is shown in PL. XVII. PLS. XVIII and XIX show two principal views of a charcoal furnace. The stock floor, or where the material is assembled preparatory to charging into the furnace, is shown in PL. XVIII, and the bottom of the furnace where the pig-iron and slag are tapped out, just after a cast has been made and while the iron is still very hot, in PL. XIX. PLS. XX, XXI, and XXII show typical scenes about a coke furnace. The top of the furnace where the materials are charged is shown in PL. XX; the hot-blast stoves in PL. XXI, and the general arrangements and surroundings of a furnace in PL. XXII.

As the charge descends gradually in the furnace it is first thoroughly dried, then any volatile constituents are driven off, and finally the iron is reduced to metal from the ore. This passes on through the furnace and absorbs carbon, and when it comes to the zone of fusion near the tuyeres the whole charge melts. The iron, by its greater specific gravity, settles to the bottom, while the slag floats on top, and both are periodically tapped from the furnace.

The reduction of the iron is accompanied by the reduction of other constituents of the ore, and the product always contains, besides carbon, which is both combined with the iron and separate as graphite, silicon, manganese, phosphorus, and sulphur. The amount of silicon depends upon the manner of running the furnace; the amount of manganese and sulphur depends partly on this and partly on the amounts in the charge, while all the phosphorus in the charge will be found in the pig metal. Occasionally other things occur in small amounts in the metal.

A few ores contain just the right amount and kind of earthy matter to furnish sufficient slag to cover the melted pig-iron in the bottom of the furnace and protect it from the direct action of the blast, which would otherwise oxidize it again and thus defeat the object of the smelting. It is more usual, however, for the ores to contain an excess of acid constituents which would form a corrosive slag that would soon destroy the lining of the furnace. It is therefore usual to add a basic flux, which is generally limestone. These ores form more slag than is required to cover the iron.

Charcoal, anthracite coal, coke, and raw bituminous coal are used as fuel, and sometimes two or more of these are used together.

CROWN POINT FURNACE.

These works consist of two blast furnaces, 70 feet by 18 feet and 60 feet by 16½ feet, built on the banks of Lake Champlain, at Crown Point, Essex County, New York. The ores used are from Crown Point Mine, near by, and from the Chateaugay Mine. The product is Bessemer pig-iron,

FIG. 1

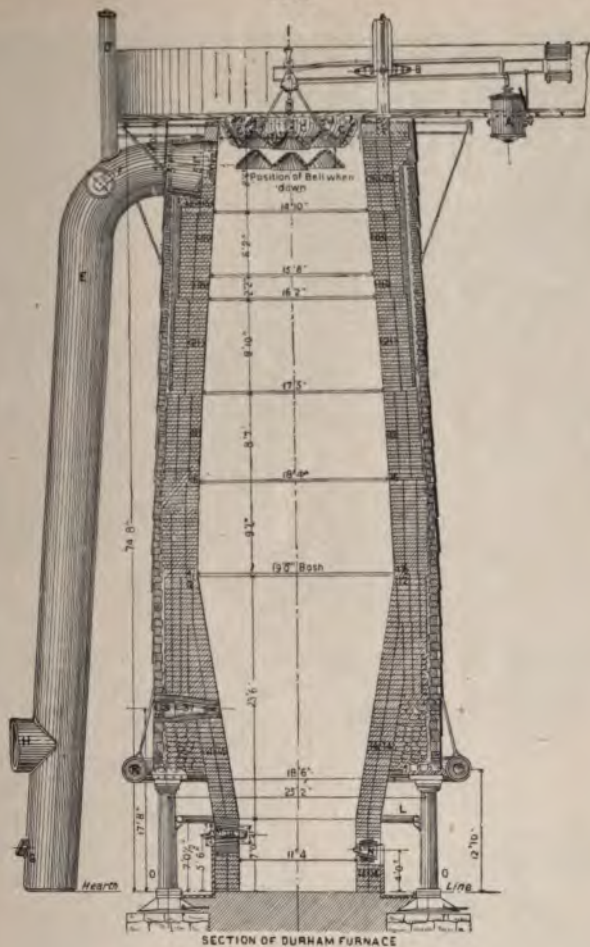
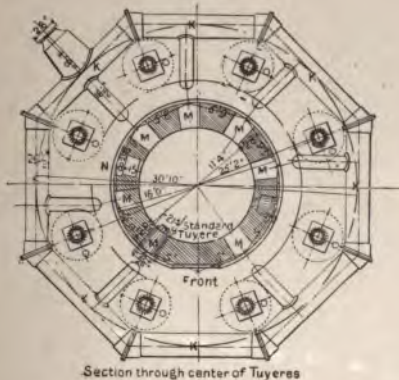


FIG. 2.



SECTION AND PLAN OF A TYPICAL BLAST FURNACE.
(See explanation, page XV.)



STOCK FLOOR OF A CHARCOAL BLAST FURNACE.
(See explanation, page XV.)

MOSS & CO. N.Y.

divided into five grades, and the capacity about 40,000 tons a year. The fuel used is generally a mixture of anthracite coal and coke, and the flux is a half-and-half mixture of magnesian limestone and marble chips. The furnaces are supplied with Siemens-Cowper-Cochran fire-brick stoves for heating the blast to about 1000° F.

The usual charge in the 70 by 18 furnace is :

	Pounds.
Anthracite coal	3,250
Coke	1,000
Lump Crown Point ore	4,175
Separated Crown Point ore	75
Forge cinder	850
Chateaugay ore	1,450
West Rutland marble	1,600
Mount Independence magnesian limestone	1,550
Total	13,950

During 29 days in July and August, 1884, the furnace produced 2,000 tons of pig ; 50 per cent. No. 1 ; 35 per cent. No. 2 ; 15 per cent. No. 3. About 10 per cent. of the product of the Crown Point Mine consists of concentrating ore, which is crushed and concentrated, part of the concentrates being smelted in a Catalan forge, similar to the Belmont forge. The collection was taken by Mr. J. B. Mackintosh, E. M., September, 1884, and shows :

Ore.

- (1) Magnetite, feldspar, and hornblende. From Chateaugay Mine, Franklin County, New York. (54425.)
- (2) Magnetite, containing quartz. Crown Point Mine, Essex County, New York. (54422.)
- (3) Concentrates, consisting of magnetite, with a little quartz. (54421.)

Fuel.

- (1) Anthracite coal. Delaware and Hudson Canal Company Mine, Wilkes-Barre, Pennsylvania. (54420.)
- (2) Coke, made from Blossburg coal, Tioga County, Pennsylvania. (54426.)

Flux.

- (1) Limestone, magnesian. Mount Independence, Rutland County, Vermont (54423.)
- (2) Marble. Rutland, Rutland County, Vermont. (54433.)

Products.

- (1) Pig-iron, No. 1. (54427.)
- (2) Pig-iron, No. 2. (54428.)
- (3) Slag, produced in making No. 2 pig-iron. (54419.)
- (4) Pig-iron, No. 3. (54429.)
- (5) Pig-iron, No. 4. (54430.)
- (6) Pig-iron, No. 5, white. (54431.)
- (7) Slag, taken from the hot blast stoves. (54424.)

From the Catalan forge are shown:

- (1) Magnetite and quartz, crushed, ready for separating. Crown Point Mine, Essex County, New York. (54436.)
- (2) Separated ore, magnetite with a little quartz. Crown Point Mine, Essex County, New York. (54435.)
- (3) Tailings, separated from Crown Point ores. (54437.)
- (4) Wrought iron, sample billet. (54432.)
- (5) Cinder. (54434.)

WARWICK FURNACE.

This furnace is situated on the line of the Philadelphia and Reading Railroad, at Pottstown, Montgomery County, Pennsylvania. It is 55 feet by 15½ feet, and provided with iron pipe stoves for heating the blast to about 860° F. The ores smelted consist of a mixture of a large variety, and it is not uncommon to use six or seven different kinds at once. The charge, when the samples of pig-iron shown were taken, was:

	Per cent.
Roasted Boyertown	30
Elba	10
Cooper Mining Company	10
Staten Island "Red"	7½
Staten Island "Black"	7½
Staten Island "Brown"	7½
Hematite	7½
Scrap cinder	10
Mill cinder	10
	<hr/>
	100
Limestone	35

The fuel used is a mixture of three-quarters anthracite coal and one-quarter coke, and 2,000 pounds will smelt 3,200 pounds of ore. The collection shows:

Ore.

- (1) Magnetite and calcite. Boyertown Mine, Berks County, Pennsylvania. (54101.)
- (2) Roasted Boyertown. (54108.)
- (3) Limonite, called "Red" ore. Staten Island, Richmond County, New York. (54103.)
- (4) Limonite, called "Brown" ore. Staten Island, Richmond County, New York. (54104.)
- (5) Limonite, called "Black" ore. Staten Island, Richmond County, New York. (54106.)
- (6) Limonite, called "Hematite." (54102.)
- (7) Magnetite, pyrrhotite, and quartz. Cooper Mining Company Mine, Chester, Morris County, New Jersey. (54105.)
- (8) Hematite, from the Island of Elba. (54107.)

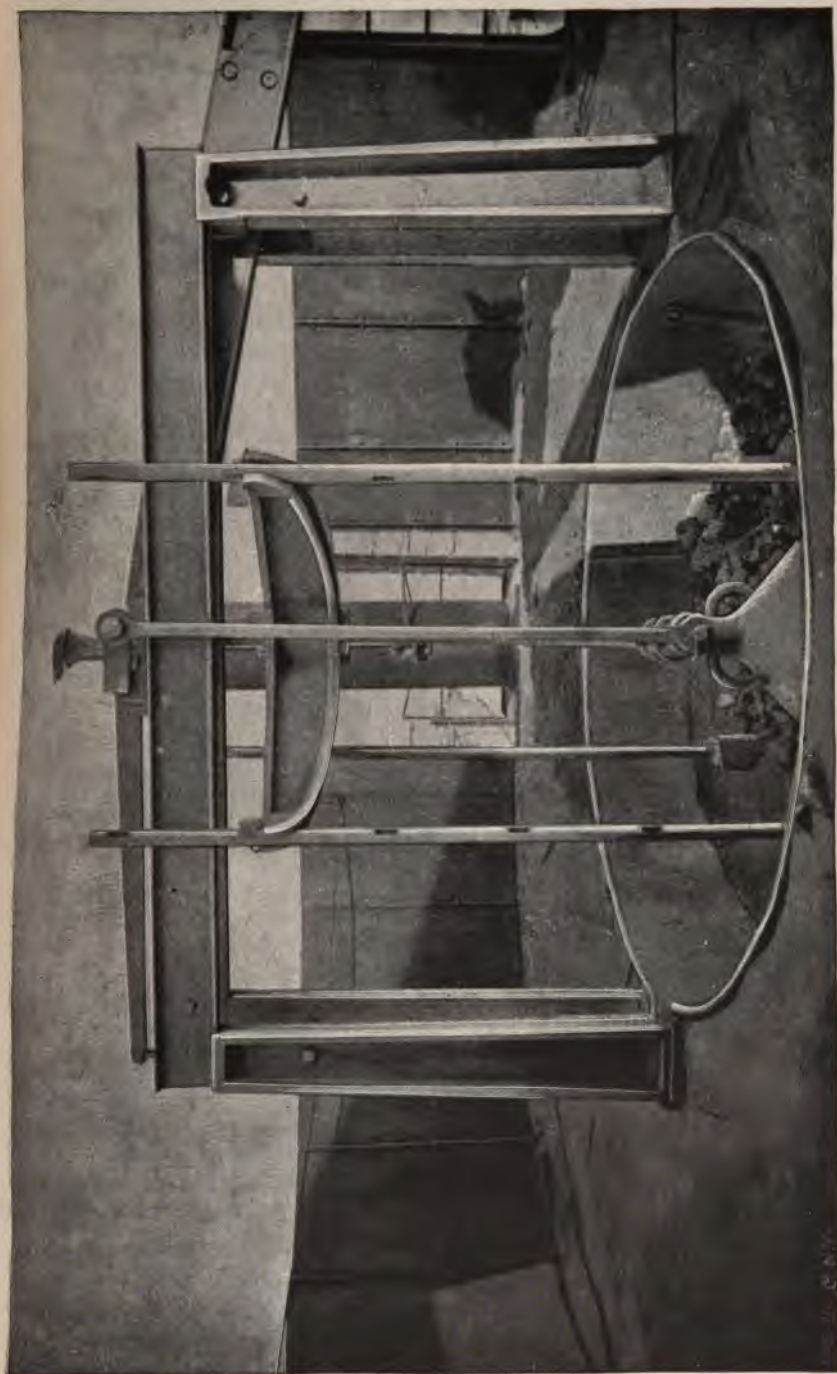
Fluxes.

- (1) Scrap cinder. (54125.)
- (2) Cinder, from nail mill. (54128.)
- (3) Limestone. Port Kennedy, Montgomery County, Pennsylvania. (54109.)



CASTING HOUSE FLOOR OF CHARCOAL BLAST FURNACE.
(See explanation, page XV.)

Moss & Co. N.Y.



TOP OF COKE BLAST FURNACE.
(See explanation, page XVI.)

Products.

- (1) Pig-iron, No. 2. (54122.)
- (2) Slag, made with No. 2 pig-iron. (54127.)
- (3) Pig-iron, No. 3. (54123.)
- (4) Slag, made with No. 3 pig-iron. (54126.)
- (5) Flue dust. (54124.)

NORTH CORNWALL FURNACE.

The North Cornwall Furnace is situated 3 miles south of Lebanon, Lebanon County, Pennsylvania. The furnace is 65 feet by 15 feet. The blast is heated by Pleyer hot ovens.

The only ore smelted is that mined from the Great Cornwall Mine. This is very high in sulphur, and generally contains a little copper, and the pig-iron is known as "Cornwall Red Short" iron. A small amount of ore from the surface is smelted direct, but most of it requires to be roasted for the removal of the sulphur. The ores carry 42 to 62 per cent. iron, 6 to 20 per cent. silica, trace to 1 per cent. copper, trace to 3 per cent. sulphur, and 0.001 to 0.004 per cent. phosphorus.

The fuel used consists of a mixture of anthracite coal and Connells-ville coke, and the flux is a limestone. The collection shows:

Ore.

- (1) Magnetite, surface specimen. (54179.)
- (2) Magnetite and pyrrhotite. (54176.)
- (3) Roasted. (54178.)

Fuel.

- (1) Anthracite coal. Draper Colliery, Schuylkill County, Pennsylvania. (54180.)
- (2) Coke, from Connells-ville, Pennsylvania. (54175.)

Flux.

- (1) Limestone. Krider's Quarry, Lebanon County, Pennsylvania. (54181.)

Products.

- (1) Pig-iron, No. 1. (54166.)
- (2) Slag, produced with No. 1 pig-iron. (54170.)
- (3) Pig-iron, No. 2. (54167.)
- (4) Slag, produced with No. 2 pig-iron. (54171.)
- (5) Pig-iron, No. 3. (54168.)
- (6) Slag, produced with No. 3 pig-iron. (54172.)
- (7) Slag, crystallized; produced with No. 3 pig-iron. (54174.)
- (8) Pig-iron, mottled. (54169.)
- (9) Slag, produced with mottled pig-iron. (54173.)
- (10) Buckshot iron, a mixture of pig-iron in small shot cemented by a difficultly fusible slag. (54177.)

By-products.

- (1) Flue dust, taken from the pipe leading to the hot-blast stove. (54165.)
- (2) Flue dust, taken from the floor of the hot-blast stove. (54164.)

The average composition of the pig-iron is shown by the following table, the samples being taken from many tons of each grade.

Pig-iron.

	No. 1.	No. 2.	No. 3.	Mottled.	White.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Silicon (Si)	2.949	2.330	1.935	1.423	0.913
Sulphur (S)	trace.	0.009	0.064	0.135	0.204
Phosphorus (P)	0.048	0.038	0.042	0.042	0.033
Combined carbon (CC)	0.084	0.048	1.229	1.361	2.766
Graphite (Gr)	3.411	3.276	2.319	2.042	0.359
Copper (Cu)	0.766	0.784	0.750	0.748	0.784
Iron, etc., undetermined	92.742	93.083	93.661	94.249	94.941
Total	100.000	100.000	100.000	100.000	100.000

Analysts, Booth, Garret and Blair.

LONGDALE IRON COMPANY.

The furnaces of this company are located at Longdale, Alleghany County, Virginia. (See PL. XXII). The ore used is limonite mined near the furnace, and the fuel is coke made from New River coal, mined at Sewall, Fayette County, West Virginia.

The collection was taken by Capt. J. E. Johnson and shows:

Ore.

- (1) Limonite, lump ore. (55902.)
- (2) Limonite, fine ore. (55900.)
- (3) Limonite, washed fine ore. (55899.)
- (4) Tailings, from washer. (55901.)

Flux.

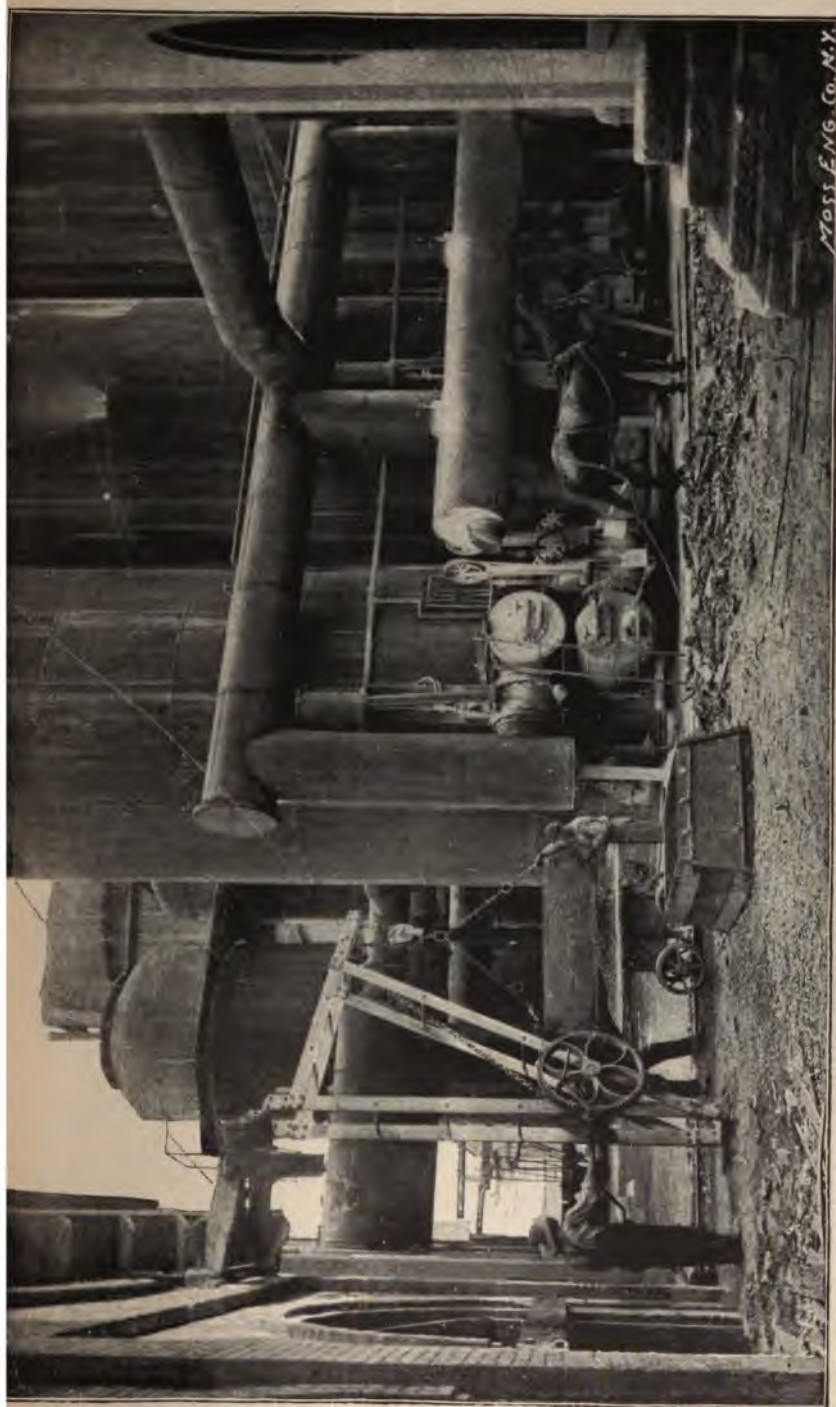
- (1) Limestone. (55903.)

Products.

- (1) Pig-iron, No. 1. (55888.)
- (2) Slag, produced in making No. 1 pig-iron. (55889.)
- (3) Pig-iron, No. 2. (55890.)
- (4) Slag, produced in making No. 2 pig-iron. (55891.)
- (5) Pig-iron, No. 3. (55892.)
- (6) Slag, produced in making No. 3 pig-iron. (55893.)
- (7) Pig-iron, mottled. (55894.)
- (8) Slag, showing crystallization; produced in making mottled pig-iron. (55895.)
- (9) Pig-iron, gray forge. (55896.)
- (10) Slag, produced in making gray forge pig-iron. (55897.)

By-products.

- (1) Cadmia, a deposit containing zinc; formed in the upper part of the furnace. (55898.)



MOSS ENGINE CO. N.Y.

FIRE-BRICK STOVES FOR HEATING BLAST OF AIR BEFORE ENTERING FURNACE.
(See explanation, page XVI.)



GENERAL VIEW OF LONGDALE FURNACES, ALLEGHENY COUNTY, VIRGINIA.
(See explanation, page XVI.)

MISSOURI FURNACE COMPANY.

The plant of this company is located south of St. Louis, at Carondelet, St. Louis county, Missouri. It was built in 1869. There are two furnaces, 56 feet by 15 feet.

The ores used are mainly from the Iron Mountain and Pilot Knob Mines. The flux is quarried near by and the fuel consists of a mixture of Bryden bituminous coal and Connellsville coke. The collection was taken by Mr. J. P. Gazzam, E. M., August, 1884, and shows:

Ores.

- (1) Hematite. Pilot Knob Mine, Iron County, Missouri. (54571.)
- (2) Hematite. Pilot Knob Mine, Iron County, Missouri. (54572.)
- (3) Hematite. Judith Springs Mine, Franklin County, Missouri. (54576.)
- (4) Hematite. Iron Mountain Mine, St. François County, Missouri. (54579.)
- (5) Hematite, washed ore. Iron Mountain Mine, St. François County, Missouri. (54575.)

Fluxes.

- (1) Limestone, compact, granular. (54582.)
- (2) Limestone, crystalline. (54583.)
- (3) Limestone. (54584.)

Fuel.

- (1) Anthracite coal. (54587.)
- (2) Bituminous coal, Bryden, Illinois. (54591.)
- (3) Coke, from Connellsville, Pennsylvania. (54595.)

Products.

- (1) Pig-iron, No. 1. Made from Pilot Knob, Iron Mountain, and Southwest hematite ores. (54598.)
- (2) Slag, produced in making No. 1 pig-iron; taken from the runner, and containing pig-iron on the bottom. (54602.)
- (3) Slag, produced in making No. 1 pig-iron. (54605.)
- (4) Pig-iron, No. 2. Made from Pilot Knob, Iron Mountain, and Southwest hematite ores. (54600.)
- (5) Slag, produced in making No. 2 pig-iron. (54607.)
- (6) Slag, self slacking, containing shots of metal: produced in making No. 2 pig-iron; buckshot iron. (54606.)
- (7) Pig-iron, No. 3. Made from Pilot Knob, Iron Mountain, and Southwest hematite ores. (54599.)
- (8) Slag, vesicular; produced in making No. 3 pig-iron. (54610.)
- (9) Slag, honeycombed: produced in making No. 3 pig-iron. (54611.)

ST. LOUIS ORE AND STEEL COMPANY.

The four furnaces of this company are located at South St. Louis, St. Louis county, Missouri. Two are 60 feet by 14 feet, one 60 feet by 15 feet, and one 65 feet by 16 feet. The ores used are mainly from Iron Mountain and Pilot Knob, and the product is Bessemer pig-iron. Coke is used for fuel. The product of the four furnaces is about 55,000 tons yearly.

The collection includes a very complete series of the pig meta different grades and two samples of slag.

Pig-iron.

Grade.	Furnace.	Silicon.	Sulphur.	Phosphorus.
No. 1	D	3.75	Trace.	0.11
No. 2	D	3.4 — 3.8	0.024 — 0.048	0.063 — 0.064
No. 2	D	3.25	0.02	0.105
No. 3	D	2.7	0.09	0.07
No. 3	D	2.7	0.063	0.063
Siliceous	D	5.4	0.00	0.065
No. 1	C	3.5	Trace.	0.09
No. 1	C or D	4.1 — 4.2	0.023 — 0.025	0.055 — 0.056
No. 2	C	3.0	0.03	0.09
No. 3	C	2.7	0.023	0.063

Slag, produced in making No. 1 pig-iron. (55408.)

Slag, produced in making No. 3 pig-iron. (55409.)

ROANE IRON COMPANY.

The blast furnaces of this company are located at Rockwood, R County, Tennessee. There are two furnaces 65 feet by 16 feet and 65 feet by 14 feet, supplied with iron pipe blast stoves. The ores consist of the local fossil ores. The flux is a limestone quarried from the bank of the Tennessee River near the furnaces, and the fuel is made from a coal mined near the furnace.

The charges in the furnaces are:

	In making—		
	No. 1 iron.	No. 2 iron.	No. 3
	Pounds.	Pounds.	Pou
Raw coal	625	625	
Coke	2,800	2,800	
Limestone	900	850	
Ore { $\frac{1}{3}$ Company	3,900	3,750	
{ $\frac{1}{3}$ Welcker			
Mill cinder	300	300	

Pressure of blast, $3\frac{1}{2}$ pounds to $3\frac{1}{2}$ pounds. Temperature of blast, 950° F.

The collection was taken by Mr. M. M. Duncan, superintendent August, 1884, and shows:

Ore.

- (1) Hematite, fossil ore. Rockwood Mines, Roane County, Tennessee. (5452)
- (2) Hematite, soft fossil ore. Crescent Mine, Roane County, Tennessee. (5453)
- (3) Hematite, hard fossil ore, taken 20 feet below the surface. Crescent Mine, Roane County, Tennessee. (54523.)
- (4) Hematite, soft fossil ore. Welcker Mine, Roane County, Tennessee. (54524.)

Flux.

- (1) Limestone. (54522.)

Fuel.

- (1) Bituminous coal, used for the manufacture of coke. (54532.)
 (2) Coke. (54521.)

Products.

- (1) Pig-iron, No. 1 foundry iron; made from fossil ores. (54501.)
 (2) Slag, produced in making No. 1 foundry iron. (54513.)
 (3) Pig-iron, No. 2 foundry iron; made from fossil ores. (54504.)
 (4) Slag, produced in making No. 2 foundry iron. (54515.)
 (5) Pig-iron, No. 3 foundry iron; made from fossil ores. (54506.)
 (6) Slag, produced in making No. 3 foundry iron. (54517.)
 (7) Pig-iron, No. 1 drillings, showing average quality. (54509.)
 (8) Pig-iron, No. 2 drillings, showing average quality. (54510.)

Accessories.

- (1) Flue dust, from gas ways of the furnace. (54512.)
 (2) Ashes, from the hot-blast stoves. (54508.)

The following series of analyses made in the laboratory of the department by Mr. J. A. Allen represent the different grades of pig-iron and the corresponding slags:

Pig-iron.

	No. 1 iron.		No. 2 iron.		No. 3 iron.	
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Silicon (Si)	2.59	2.63	2.98	2.97	2.80	3.12
Phosphorus (P)	1.32	1.35 •	1.20	1.27	1.25	1.35
Sulphur (S)	0.024	0.027	0.025	0.027	0.026	0.041
Manganese (Mn)	0.63	0.74	0.61	0.78	0.68	0.62

Slag.

	No. 1.	No. 2.	No. 3.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Silica (SiO ₂)	33.10	33.15	34.85
Alumina (Al ₂ O ₃)	18.15	17.36	18.90
Protoxide of iron (FeO)	1.00	0.58	0.85
Protoxide of manganese (MnO)	0.56	0.54	0.38
Lime (CaO)	38.08	39.52	37.30
Sulphide of calcium (CaS)	2.70	2.47	2.32
Magnesia (MgO)	6.79	5.96	6.32
	100.38	99.58	100.92

THE APPLICATION OF IRON.

THE FAGERSTA STEEL WORKS.

These works are located at Westanfors, Fagersta, Sweden, and manufacture Bessemer steel of very high grade, partly due to the great

purity of the ores used and partly due to the skill displayed in carrying on the works.

The iron ores and limestone employed at the charcoal blast furnaces at Westanfors and Fagersta consist of the following component parts:

	Iron ore from the mines of—			Limestone from Hedkärna.
	Östra Stortäkten.	Granrot.	Gröndal.	
Silica (SiO_2)	27.40	3.10	6.35	10.82
Alumina (Al_2O_3)	1.30	2.05	1.15	7.15
Lime (CaO)	2.16	1.20	2.65	36.61
Magnesia (MgO)	1.76	1.05	3.85	6.86
Protoxide of manganese (MnO)	0.81	10.40	5.50	1.25
Protoxide of iron (FeO)	20.74	23.50	22.82	.....
Sesquioxide of iron (Fe_2O_3)	46.14	52.44	50.78	.....
Carbonic acid (CO_2) .....	.....	6.10	5.95	37.18
Phosphoric acid (P_2O_5)	0.016	0.009	0.014	0.007
	100.416	99.909	99.064	99.877

The average chemical composition formed by the mixture of these iron ores with the limestone, employed as flux, is as follows:

	Per cent.
Silica (SiO_2)	11.93
Alumina (Al_2O_3)	2.50
Lime (CaO)	7.51
Magnesia (MgO)	2.76
Protoxide of manganese (MnO)	5.63
Protoxide of iron (FeO)	19.76
Sesquioxide of iron (Fe_2O_3)	43.89
Carbonic acid (CO_2)	6.02
Phosphoric acid (P_2O_5)	0.013
	100.013

Such a charge yields, upon smelting, from 48 to 50 per cent. of pig-iron, which is tapped direct from the blast furnace into the Bessemer converters, and consists on the average of the following component parts:

	Per cent.
Carbon, combined (CC)	3.460
Carbon, graphitic (CGr)	1.289
Silicon (Si)	0.771
Manganese (Mn)	4.491
Phosphorus (P)	0.027
Sulphur (S)	trace.

The blast furnace slag contains :

	Per cent.
Silica (SiO_2)	41.96
Alumina (Al_2O_3)	7.02
Lime (CaO)	25.04
Magnesia (MgO)	17.75
Protoxide of manganese (MnO)	6.57
Protoxide of iron (FeO)	0.23
Alkalies not determined. ....	.....
	<hr/> 98.57

As no spiegeleisen or ordinary cast-iron is employed to recarburize the metal, the "blow" must be stopped when the proportion of carbon in the steel is reduced to the proper degree. Notwithstanding this, the steel is entirely free from red-shortness.

The following analyses show the chemical compositions of the various classes of steel employed for the purposes specified :

	Carbon.	Silicon.	Mangane- nese.	Phosphor- us.	Sulphur.
	Per cent.	Per cent.	Per cent.	Per cent.	
(a) Steel for soft plates, railway axles, etc.	0.085	0.008	Trace.	0.025	Trace.
(b) Steel for gun barrels, shafts, etc.	0.25	0.036	0.234	0.022	Do.
(c) Soft steel for tools, saws, etc.	0.70	0.032	0.256	0.023	Do.
(d) Hard steel for tools, chisels, turning tools, etc.	1.05	0.067	0.355	0.028	Do.

An analysis of the slag from the converter, taken at the close of the process, shows its composition to be as follows :

	Per cent.
Silica (SiO_2)	46.70
Alumina (Al_2O_3)	4.24
Lime (CaO)	0.48
Magnesia (MgO)	0.17
Protoxide of manganese (MnO)	32.37
Protoxide of iron (FeO)	15.63
	<hr/> 99.59

KIRKALDY'S EXPERIMENTAL INQUIRY INTO THE MECHANICAL PROPERTIES OF FAGERSTA STEEL.

Mr. David Kirkaldy, of London, has made a very elaborate and systematic investigation of the product of the Fagersta works. The examination was designed to show the actual mechanical properties of the average product, and this was carried out very carefully.

A selection of the specimens tested has been placed on exhibition in the Museum.

Series A.

To ascertain the mechanical properties of twelve hammered bars of various degrees of hardness, or the behavior of the steel when subjected to the various stresses which occur in engineering works, namely,

pulling, thrusting, bending, twisting, and shearing, bars containing 1.2, 0.9, 0.6, 0.3 of carbon, three of each, were used to obtain an average. The bars were all hammered to 2 inches square, were all similarly prepared and all similarly tested, so that the results are strictly comparable. Throughout the entire series of experiments the stress is expressed in pounds per square inch of the specimen's original area unless it is otherwise stated.

First. Pulling or tensile stress—strength.—Elastic stress, 62,033, 63,066, 58,100, 43,100 pounds; ultimate stress, 85,200, 106,603, 102,632, 61,312 pounds.

Ductility.—Contraction of the specimen's area at fracture, 2.65, 6.11, 14.43, 61.52 per cent. of the original area. Ultimate extension, or the amount that the specimen has stretched, 1.8, 5.1, 6.6, 16.5 per cent. of its original length. In the order of their carbon contents the highest being given first.

Characteristics of fracture.—Bars 1.2, 0.9, 0.6, all broke more or less suddenly, and are wholly granular and right-angled fractures; the 0.3, or softest, broke very gradually, appearance wholly silky and of cup-form. In the granular fractures some radiate from the center, whilst others from or near the side of specimen presenting a fan-like appearance.

Second. Thrusting or compressive stress.—Specimens equal to 1, 2, 4, and 8 diameters, showed the following results under elastic stress:

Length.	Elastic stress.			
	1.2	0.9	0.6	0.3
	Pounds.	Pounds.	Pounds.	Pounds.
One diameter	64,000	62,666	60,000	39,000
Two diameter	63,333	58,666	57,333	42,000
Four diameter	62,333	58,666	53,333	41,000
Eight diameter	61,666	58,000	52,666	40,666
Total mean	62,833	59,499	55,833	40,667

The stress becomes gradually reduced as the length is increased, the hardest bars under thrusting giving the highest results, which was found not to be the case under pulling stress.

Length.	Ultimate stress.			
	1.2	0.9	0.6	0.3
	Pounds.	Pounds.	Pounds.	Pounds.
Two diameter	169,907	173,287	156,000	121,333
Four diameter	133,333	117,560	105,333	81,700
Eight diameter	102,173	95,207	84,827	47,513
Total mean	135,138	128,685	115,387	83,535

Effects.—All of the 1-diameter lengths bulged, three of the 2-diameter detruded or fractured by one portion angularly sliding off the other, whereas the others assumed a skew form without fracture. All of the 4-diameters likewise changed to a skew form except the softest, which buckled in the center without fracturing, as was also the case with all of the 8-diameters, excepting one of the hardest, which snapped after buckling.

Third. Bending or transverse stress.—Strength.—The bars planed to 1.90 by 1.90 inches placed on bearings 20 inches apart, supported in the center showed at elastic stress, 21,133, 21,700, 18,333, 15,767 pounds, and at ultimate stress, 32,589, 43,833, 38,145, 25,283 pounds, each being the mean of the three bars tested, given in the order of carbon contents.

Stiffness.—The ultimate deflection, at rupture, or that when the greatest stress was reached, was as follows: 0.78, 1.49, 3.31, 5.11 inches.

Effects.—The three bars 1.2, and the three bars 0.9, and one of the 0.6 broke, presenting a granulated fracture, while the others doubled up without breaking. In order to develop the change in the form of these and of similar bars when tested some had circles drawn on their sides, some diagonal lines, others transverse lines, and others both transverse and longitudinal lines.

Fourth. Twisting stress.—These specimens were formed with three square bosses. In testing the one in the center remains comparatively stationary, whilst those at each end are made to rotate simultaneously in the same direction.

Strength.—These bars having a sectional area of 1 square inch and a torsional length of 8 diameters, resisted at elastic stress 1,135, 1,125, 1,083, 763 pounds, acting upon a lever 12 inches in length on each end of the specimen; and at ultimate stress 2,120, 2,336, 2,261, 1,520 pounds.

Rigidity.—The amount of ultimate torsion was 0.291, 0.793, 1.021, 3.219, each of these being the mean of six. On examining the detailed results it will be noticed that both halves of the specimen do not fracture at the same time, thus B 1069, the first half, gave way at 0.207, whereas the other half was moved to 0.227 before fracture occurred, the other specimens varying more or less.

Effects.—The lines on the three hardest bars, 1.2, show that they have been twisted from two to four tenths of one turn before fracturing, bars 0.9 from seven to nine tenths, 0.6, from nine-tenths to one turn and one-tenth, whilst the softest from two and a half turns to three and three-quarters previous to being fractured. The hardest bars all broke suddenly, the fractures being composed of many spiral formed pieces and all presenting a fine granular appearance. Those of medium hardness all broke with a well-defined spiral fracture at an angle varying from 55 to 57 degrees, a straight fracture between the extremities of the spiral completing the separation, presenting a fine granular appearance. The softest bars broke very differently to the others, as they all parted right across, or in a plane perpendicular to the axis, presenting a smooth, shining fracture.

Fifth. Shearing stress.—This is the stress that comes into action on the pins of bridge and roof links, namely, a center link pulling in one direction while the two side links pull in the opposite direction, thus tending to cut or shear the pin at the two junctions.

Strength.—Ultimate shearing stress 61,412, 79,737, 71,648, 45,410 pounds per square inch, given according to carbon contents, each being the mean of experiments on three bars. These experiments prove that the strength to resist a shearing is on an average one-fourth less than the tensile strength.

Hardness.—As shown by the amount of detrusion before rupture 0.193, 0.249, 0.281, 0.323 parts of 1 inch.

Effects.—The hardest bars, 1.2, were very slightly cut, but broke suddenly into many small pieces at the junctions; 0.9, more cut and fewer pieces; 0.6, edges more curved on reverse sides, and cut, only two small pieces; the fractures being all granular, excepting where cut Bars 0.3, or the softest, reverse sides more curved and cut, and remaining portions parting with a smooth shining surface.

Series B.

Steel ingots cast to 6 inches square were tested by pulling to ascertain the mechanical effects produced by their being hammered down to 5, 4, 3, and 2 inch square bars. Four ingots, of different degrees of hardness, containing 0.8, 0.6, 0.4, and 0.2 of carbon, were operated upon.

One set was tested as received, the other set as annealed. The differences between the unannealed and the annealed are more marked in the elastic than in the ultimate stress borne.

Description. As received.	Elastic stress.			Ultimate stress.		
	Unannealed.	Annealed.	Difference.	Unannealed.	Annealed.	Difference.
	Pounds.	Pounds.	Per cent.	Pounds.	Pounds.	Per cent.
0.8	53,457	41,500	22.3	75,959	70,608	7.1
0.6	41,743	39,886	4.4	75,639	74,481	1.5
0.4	31,943	29,671	7.1	65,001	62,334	4.1
0.2	27,800	25,514	8.2	56,401	54,300	3.7
Total mean	38,736	34,143	11.86	68,250	65,431	4.13

Annealing the bars gives 11.86 per cent. less in the elastic and 4.13 per cent. in the ultimate stress.

Description. Hammered to 2 inches square.	Unannealed.			
	Elastic stress.		Ultimate stress.	
	Pounds.	Per cent.	Pounds.	Per cent.
0.8	from 47,650 to 66,500	39.1	from 67,162 to 98,624	46.8
0.6	from 38,550 to 47,700	23.7	from 68,230 to 97,887	43.5
0.4	from 28,300 to 39,200	38.5	from 55,223 to 75,013	35.8
0.2	from 22,200 to 35,200	58.5	from 52,898 to 59,940	13.3
Total mean	from 34,175 to 47,150	38.0	from 60,878 to 82,866	36.1

The increase in strength due to hammering is not constant for the four classes, for whilst the increase is greatest in the softest material under elastic stress it is just the reverse under ultimate stress as is also shown by the annealed specimens.

Description. Hammered to 2 inches square.	Annealed.			
	Elastic stress.		Ultimate stress.	
	Pounds.	Per cent.	Pounds.	Per cent.
0.8.....	from 38,850 to 47,500	22.3	from 63,542 to 86,073	35.5
0.6.....	from 37,150 to 46,300	24.6	from 74,043 to 91,807	24.0
0.4.....	from 26,150 to 36,500	39.6	from 53,002 to 70,787	33.6
0.2.....	from 20,150 to 33,100	64.3	from 52,800 to 56,347	6.7
Total mean	from 30,575 to 40,850	33.6	from 60,847 to 76,253	25.3

The general average shows 33.3 per cent. as the gain in strength of the steel due to hammering 6-inch ingots down to 2 inch square bars.

Hammering also increases the ductility of the material, as proved by the specimens becoming more contracted in area at fracture, and also by the increase in the ultimate extension.

Description. Hammered to 2 inches square.	Contraction of area.		Ultimate extension.	
	Unannealed.	Annealed.	Unannealed.	Annealed.
	Per cent.	Per cent.	Per cent.	Per cent.
0.8.....	from 1.5 to 3.2	from 2.1 to 8.1	from 1.1 to 2.2	from 1.7 to 5.5
0.6.....	from 2.5 to 28.4	from 14.9 to 46.0	from 2.0 to 10.2	from 7.2 to 12.7
0.4.....	from 4.2 to 52.5	from 5.2 to 57.6	from 3.4 to 17.9	from 4.3 to 19.1
0.2.....	from 11.9 to 61.3	from 27.1 to 64.1	from 11.6 to 22.5	from 18.2 to 22.2
Total mean	from 5.0 to 36.3	from 12.3 to 44.0	from 4.5 to 13.2	from 7.8 to 14.9

Series C.

The mechanical effects produced on steel bars containing 1.0, 0.5, 0.15 of carbon, by reducing to various sizes, viz, 3, 2½, 2, 1½, 1 and ½ inch square bars, some by hammering, others by rolling were next tested.

In this series, as in the preceding, and for the same reasons, specimens in duplicate were prepared and tested as unannealed and annealed. Six bars *hammered* from 3-inch square to ½-inch square, and six bars *rolled* to the same sizes.

Description.	Elastic stress.			Ultimate stress.		
	Unannealed.	Annealed.	Difference.	Unannealed.	Annealed.	Difference.
	Pounds.	Pounds.	Per cent.	Pounds.	Pounds.	Per cent.
Hammered :						
1.0.....	73,383	56,017	23.6	99,223	95,961	3.3
0.5.....	48,850	38,823	20.4	81,207	75,542	6.9
0.15.....	40,633	28,617	29.5	60,834	53,735	11.6
Total mean	54,289	41,152	24.5	80,421	75,079	7.2
Rolled :						
1.0.....	67,900	52,087	23.3	105,764	100,415	5.0
0.5.....	39,283	35,917	8.6	79,470	76,477	3.7
0.15.....	28,317	25,233	10.9	56,843	53,238	6.3
Total mean	45,167	37,739	14.3	80,699	76,710	5.0

Hammered bars gave 24.5 per cent. less in the elastic and 7.2 per cent. in the ultimate, and rolled bars 14.3 and 5 per cent. as the result of annealing.

The softening of the steel due to annealing is also shown by—

Description.	Contraction of area.			Ultimate extension.			Appearance of fracture.	
	Unannealed.	Annealed.	Difference.	Unannealed.	Annealed.	Difference.	Unannealed, granular.	Annealed, granular.
Hammered:	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
1.0	6.2	9.3	3.1	2.6	4.9	2.3	98	98
0.5	32.8	41.9	9.1	13.1	14.8	1.7	41	35
0.15	55.2	66.9	11.7	20.0	21.0	1.0	11	1
Total mean ..	31.4	39.3	7.9	11.9	13.6	1.7	50	45
Rolled:								
1.0	6.7	11.7	5.0	3.1	4.9	1.8	99	95
0.5	20.6	34.9	14.3	11.5	11.8	0.3	72	55
0.15	56.4	67.7	11.3	26.2	27.0	0.8	17	0
Total mean ..	27.9	38.1	10.2	13.6	14.6	1.0	63	50

The increase in the amount of stress borne, both elastic and ultimate, due to the additional work in the manufacture in reducing from 3 inch square to $\frac{1}{2}$ inch square is shown by—

Description.	Unannealed.			
	Elastic stress.		Ultimate stress.	
	<i>Pounds.</i>	<i>Per cent.</i>	<i>Pounds.</i>	<i>Per cent.</i>
Hammered:				
1.0	From 61,500 to 94,200	53.2	From 70,262 to 135,720	93.2
0.5	From 38,800 to 78,300	101.8	From 70,080 to 95,960	36.9
0.15	From 28,400 to 57,500	102.5	From 56,623 to 72,140	27.4
Total mean ..	From 42,900 to 76,667	78.7	From 65,655 to 101,273	54.2
Rolled:				
1.0	From 60,200 to 78,600	30.6	From 75,605 to 139,980	85.1
0.5	From 30,400 to 46,800	53.9	From 62,393 to 90,730	45.4
0.15	From 22,900 to 33,800	47.6	From 52,962 to 60,780	14.8
Total mean ..	From 37,833 to 53,067	40.3	From 63,653 to 97,163	52.6

The high percentages were partly due to *cold hammering* and *cold rolling*, and do not proceed wholly from the additional work bestowed, as is shown by—

Description.	Annealed.			
	Elastic stress.		Ultimate stress.	
	Pounds.	Per cent.	Pounds.	Per cent.
Hammered:				
1.0.....	From 46,700 to 69,700	49.6	From 70,925 to 122,760	73.1
0.5.....	From 29,800 to 47,800	60.4	From 69,640 to 82,120	17.9
0.15.....	From 24,600 to 31,900	29.7	From 51,587 to 56,870	10.2
Total mean.....	From 33,700 to 49,800	47.8	From 64,051 to 87,250	36.2
Rolled:				
1.0.....	From 44,300 to 64,600	46.3	From 72,912 to 127,980	75.5
0.5.....	From 27,600 to 41,200	49.3	From 60,193 to 80,210	33.3
0.15.....	From 20,900 to 27,900	33.5	From 50,227 to 52,640	4.8
Total mean.....	From 30,933 to 44,633	44.3	From 61,111 to 86,943	42.8

These percentages are the real values strictly due to the additional work expended in reducing the bars from 3 inch to $\frac{1}{2}$ inch square. The increased ductility of the material resulting from the processes of manufacture, as evinced by increased contraction of area at fracture, is presented in the following table:

Description.	Contraction of area.	
	Unannealed.	Annealed.
	Per cent.	Per cent.
Hammered:		
1.0.....	From 0.4 to 20.0	From 1.6 to 25.0
0.5.....	From 4.4 to 47.0	From 8.4 to 55.0
0.15.....	From 41.9 to 59.0	From 52.3 to 75.0
Total mean.....	From 15.6 to 42.0	From 20.8 to 51.7
Rolled:		
1.0.....	From 0.5 to 20.0	From 2.8 to 30.0
0.5.....	From 4.4 to 43.0	From 5.4 to 51.0
0.15.....	From 57.8 to 72.0	From 64.2 to 78.0
Total mean.....	From 20.9 to 45.0	From 24.1 to 53.0

Series D.

Ten tests were made to ascertain the increments of length, with corresponding sets, under a gradually increased pulling stress of rolled steel plates of various thickness, containing 0.15 of carbon.

Two plates of each of five different thicknesses, viz, one-eighth, one-quarter, three-eighths, one-half, and five-eighths inch were used.

Series E.

Ten tests were made to ascertain the decrements of length, with corresponding sets, under a gradually increased thrusting stress, specimens cut from same samples as series D.

The average increments of the first series are the average decrements of the second series as shown in table. As 20,000 pounds is the highest stress common to all the specimens it will now be used as standard.

Description.	Increments.			Decrements.			Difference.	
	At 20,000 pounds in 100 inches.	Per thous. and pounds.	Per ton, 2,240 pounds.	At 20,000 pounds in 100 inches.	Per thous. and pounds.	Per ton, 2,240 pounds.	Increments greater.	Decrements less.
	<i>Inch.</i>	<i>Per unit.</i>	<i>Per unit.</i>	<i>Inch.</i>	<i>Per unit.</i>	<i>Per unit.</i>	<i>Per cent.</i>	<i>Percent.</i>
Unannealed	0.0616	0.0000308	0.00006899	0.0564	0.0000282	0.00006317	9.22	8.44
Annealed...	0.0674	0.0000337	0.00007549	0.0584	0.0000292	0.00006541	15.41	13.35

Description.	Elastic stress.				Ultimate stress.			
	Large (series F ¹).	Small (series F ¹).	Long (series D).	Mean.	Large (series F ¹).	Small (series F ¹).	Long (series D).	Mean.
Unannealed:	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>
1½.....	53,300	50,500	38,900	47,567	74,915	71,940	55,135	67,330
1¼.....	37,900	35,400	35,600	36,300	60,480	56,740	54,140	57,120
1⅓.....	29,500	29,300	25,400	28,067	51,456	50,345	48,925	50,243
1½.....	31,100	30,800	27,500	29,800	55,803	54,425	50,160	53,463
1⅔.....	28,000	28,300	26,100	27,467	52,924	52,475	49,280	51,560
Mean.....	35,960	34,860	30,700	32,840	59,116	57,185	51,528	55,943
Annealed:								
2½.....	35,500	33,200	26,700	31,800	57,485	55,459	45,460	52,801
2¼.....	33,800	30,500	29,800	31,367	54,543	52,715	49,605	52,288
2⅓.....	28,900	28,100	25,900	27,633	51,076	50,350	46,740	49,389
2½.....	27,800	27,900	27,300	27,667	51,338	50,842	49,490	50,557
2⅔.....	25,500	25,700	25,200	25,467	50,432	50,025	47,455	49,304
Mean.....	30,300	29,080	26,980	28,787	52,975	51,878	47,750	50,868

The large specimens give somewhat higher results than the small, whilst the long ones are very considerably less.

Series F.

To ascertain the mechanical effects and the variations caused by difference in the shape and proportion of specimens, rolled steel plates of various thicknesses, tested under pulling stress, the same material as series D, were tested.

The larger specimens were 10 by 10 inches; the smaller specimens were 4½ by 1½ inches. In order to develop the change in the form of the large specimens when under stress, some of the plates had circles, and others diagonal lines drawn on the surface. The altered appearance of these circles and lines at the conclusion of the experiment is shown by a plate.

It is interesting to compare the result obtained by testing the large

and the small pieces, with those of a hundred inches already given under series D.

Description.	Contraction of area.				Ultimate extension.			
	Large (series F ¹).	Small (series F ¹).	Long (series D).	Mean.	Large (series F ¹).	Small (series F ¹).	Long (series D).	Mean.
Unannealed:	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
1½.....	43.1	47.1	37.9	42.7	10.8	13.5	5.21	9.45
1½.....	43.5	54.2	59.7	54.1	28.2	35.5	10.17	24.41
1½.....	59.3	62.5	71.0	64.3	36.1	41.5	20.64	32.57
1½.....	50.0	58.6	61.2	56.6	36.4	40.0	16.30	30.78
1½.....	55.1	61.7	60.7	59.2	37.2	44.7	17.95	33.01
Mean.....	51.2	56.8	58.1	55.4	29.7	35.0	14.05	26.04
Annealed:								
2½.....	57.1	60.8	64.6	60.8	22.9	28.4	10.98	20.37
2½.....	69.9	63.5	67.5	64.0	33.8	40.1	16.88	29.99
2½.....	63.4	63.6	69.6	65.5	35.8	42.0	18.19	31.76
2½.....	61.0	65.1	64.3	63.5	38.5	42.5	19.15	33.08
2½.....	62.0	64.3	63.1	63.1	34.4	43.5	17.45	31.51
Mean.....	60.9	63.5	65.8	63.4	33.1	39.3	16.53	29.52

These results show the large specimens, which held the highest stress, have contracted least, and the long specimens, which held the lowest stress, have contracted most, thus to some extent accounting for the differences in the stress.

Series F.

To ascertain the mechanical effects produced on steel plates of various thicknesses by holes, some drilled, others punched, tests under pulling stress were made. The same material as series D, E, and F was tested.

There are three rows of five each of rivet holes, 3 inches between their centers, the pitch of the five holes across the plate being 2½ inches.

In the five unannealed plates with drilled holes the loss of tensile strength ranges from 21.72 to 25.13, the average being 23.21 per cent.; and those annealed from 23.04 to 27.08, average 24.92 per cent., yielding a total average of 24.06 per cent. The loss in no instance was nearly so great as that representing the material removed, the mean being 24.06 against 30.80, or 6.74 per cent. less.

In the five unannealed plates with punched holes the loss of tensile strength ranges from 30.50 to 49.04, the mean being 37.85. The greatest loss, 49.04, occurs in the ½-inch plate, and is 45.17 in the ¼-inch, and least in the ⅜-inch plate, which the other experiments proved to be the softest of the five, and consequently the punching had not acted so injuriously as in the other two. The loss from punching is not constant, but varies with the thickness and also with the hardness of the material. That

punching hardens is proved by the five-eighths-inch and one-half-inch plates only stretching 1.9 and 3.2 per cent., and also by their breaking very suddenly, as attested by the appearance of the fracture, one being wholly and the other within 5 per cent. of wholly granular, whereas the others are wholly silky. Heating and annealing the specimens after being punched is found to counteract to a considerable extent the injurious action, the loss in the five-eighths-inch being reduced from 49.04 to 31.32, and the one-half-inch from 45.17 to 30.12, and instead of extending 1.9 rose to 20.7, and from 3.2 to 19.3 per cent., and the appearances of the fractures from wholly granular to wholly silky in the one, and from 95 per cent. granular to wholly silky in the other. The mean loss of the five annealed is 31.63 and 37.85 in the unannealed, their joint average being 34.74 per cent. This average loss, however, would have been much greater had the material not been so extremely soft and ductile.

Series G.

The effects of bulging stress on rolled steel plates of various thicknesses was tested upon the same material as series D, E, and F.

The specimens for the above test were disks, 12 inches in diameter, cut out in a lathe, and pressed through an aperture 10 inches in diameter, the end of the plunger being turned to a radius of 5 inches. The two woodcuts which accompany the tabulated report of the results, series G, show the form of the specimen previous to and after experiment. Ten pieces were tested as rolled, unannealed, and ten after being annealed.

The following stresses were required to force the specimens of the various thicknesses through the aperture :

Thickness.	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{3}{16}$
	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>
Unannealed	215,685	162,735	104,845	71,800	35,397
Annealed	198,005	154,250	95,605	59,425	25,435

All the specimens stood the ordeal without the slightest sign of any crack or defect in the manufacture. The clear tone given out, on being struck, by all the specimens after being bulged, excepting those that buckled owing to their thinness, proves the soundness of the material.

M A N G A N E S E.

MANGANESE ORE.

The ores of manganese consist of various oxides of manganese, both hydrous and anhydrous, and find application for two distinct purposes, bleaching and steel-making. For bleaching purposes the manganese ore is dissolved in hydrochloric acid which gives off free chlorine that

can be utilized for bleaching in a variety of ways. The amount of chlorine given off depends upon the amount of binoxide of manganese (MnO_2) in the ore, and this determines the value of the ore. Ores containing less than 70 per cent. of binoxide of manganese have little or no value. In steel-making the ores are smelted, either alone or mixed with iron ores, in a shaft furnace, just as iron ores are smelted. For this purpose the ores must contain only a very small amount of phosphorus. The product is known as spiegeleisen or ferromanganese, according to the amount of manganese it contains. It contains a large amount of combined carbon, and is used in the steel processes to give carbon to the metal. It also improves the physical properties of the metal by introducing a little manganese, which aids especially in producing sound castings. Specimens of spiegeleisen and ferromanganese will be found in the steel collections.

Besides the manganese ores in the Census series of iron ores, the following characteristic specimens are shown:

- (1) Crystallized and massive. Floyd County, Georgia. (56354.)
- (2) Crystallized and massive. Chumney Hill, Bartow County, Georgia. (56349.)
- (3) Massive. Dobbins Mine, Bartow County, Georgia. (56344.)
- (4) Massive. Independence County, Arkansas. (56401.)

NICKEL AND COBALT.

NICKEL MINERAL.

MILLERITE.

Composition: NiS . Sulphide of nickel, containing nickel 65 per cent. and sulphur 35 per cent.

It crystallizes in the rhombohedral system, crystals usually very much elongated. It also occurs in radiated and columnar coatings. It varies in hardness from 3 to 3.5, and in specific gravity from 4.6 to 5.6, has a full metallic luster and brass-yellow color, with often a gray iridescent tarnish. Millerite is an important nickel mineral, but is seldom found pure in large amounts.

To illustrate the occurrence of millerite the following specimen is shown here. Other specimens are included in the ore series:

- (1) Thin, fibrous coating on decomposed rock. Gap Mine, Lancaster County, Pennsylvania. (65307.)

COBALT AND NICKEL MINERAL.

LINNÆITE.

Composition: $2CoS + CoS_2$. Sulphide of cobalt, containing cobalt 58 per cent. and sulphur 42 per cent. The cobalt is always replaced by more or less nickel, and generally also by copper.

It crystallizes in the isometric system in cubes and octahedrons and

combinations of these. Its hardness is 5 and its specific gravity from 4.8 to 5. It has a metallic luster and steel-gray color, giving a red tarnish.

Linnæite is an important source of cobalt and nickel in some of the Missouri lead mines, where it is found associated with lead and copper ores. To illustrate the occurrence of linnæite three specimens are shown :

(1) Crystallized, with chalcopyrite, in magnesian limestone. Mine La Motte, Madison County, Missouri. (56109.)

(2) With chalcopyrite, in magnesian limestone. Mine La Motte, Madison County, Missouri. (65309.)

(3) Crystallized, also radially fibrous, with decomposed material. Mine La Motte, Madison County, Missouri. (17111.)

NICKEL AND COBALT ORES.

The chief source of nickel and cobalt is not the nickel and cobalt minerals, but the magnetic sulphide of iron, pyrrhotite, which frequently carries a small percentage of these metals. Millerite is, however, frequently found with the pyrrhotite. The mining of these ores in the United States has been mostly confined to two localities, the pyrrhotite mine at Gap, Lancaster County, Pennsylvania, and some of the lead mines of Missouri, especially Mine La Motte, where linnæite occurs with the lead ore and nickel and cobalt are obtained in a matte in the lead smelting. Other localities have at times produced small amounts of these ores. Recently mines at Lovelocks, in Nevada, have produced considerable nickel and cobalt. The ore at the surface contained oxidized products, but as depth was gained the sulphide ores appeared.

To illustrate the occurrence of nickel and cobalt ores four specimens are shown :

Oxidized ore.

(1) Annabergite and erythrite, on decomposed material. Soudan Mine, Lovelocks Humboldt County, Nevada. (56463.)

Sulphide ore.

(1) Nickeliferous pyrrhotite, chalcopyrite, hornblende, enstatite, and quartz; two characteristic samples. Averages 2 to 3 per cent. nickel and 0.5 per cent. cobalt. Gap Mine, Lancaster County, Pennsylvania. (18725.)

(2) Linnæite and chalcopyrite, in magnesian limestone. Mine La Motte, Madison County, Missouri. (65384.)

(3) Millerite, in long, thin crystals and rosettes of small, fine crystals, in decomposed material. Soudan Mine, Lovelock's, Humboldt County, Nevada. (66582.)

APPLICATION OF NICKEL AND COBALT.

The applications of nickel and cobalt are illustrated by the following collection from the American Nickel Works of Mr. Joseph Wharton at Camden, New Jersey.

Nickel.

- (1) Matte, obtained by smelting the ores of the Gap Mine. (31600.)
- (2) Cast, anodes for nickel plating, five different styles. (30936.)
- (3) Cast, anode for nickel plating that has been in use. (29921.)
- (4) Cast, in rods, three sizes. (30937.)
- (5) Cast, turned down to a small rod. (10171.)
- (6) Cast, in cubes, for making anodes. (30949.)
- (7) Cast, in grains, for making anodes. (30948.)
- (8) Wrought, square bar, hammered. (30938.)
- (9) Wrought, rolled into sheets. (51182.)
- (10) Wrought, rolled rod. (29678.)
- (11) Plating, three samples. (29923.)
- (12) Plating, wrought iron with 10 per cent. of nickel on each side, rolled down. (33310.)

Salts of Nickel.

- | | |
|--|------------------------|
| (1) Oxide. (30952.) | (3) Nitrate. (30962.) |
| (2) Chloride. (30963.) | (4) Sulphate. (30953.) |
| (5) Sulphate of nickel and ammonia, for plating purposes. (30954.) | |
| (6) Sulphate of nickel and ammonia, crystallized in a dome. (30955.) | |

Cobalt.

- (1) Cast, anodes for plating, four sizes. (29919.)
- (2) Plating. (29923.)
- (3) Plating. (29679.)
- (4) Blue glass, colored by oxide of cobalt. (30940.)
- (5) Blue glass, colored by oxide of cobalt; made into gallipots. (30941.)
- (6) Blue glass, colored by oxide of cobalt; made into bottles. (30915.)

Salts of Cobalt.

- (1) Oxide. (30957.)
- (2) Chloride. (30958.)
- (3) Nitrate. (30959.)
- (4) Sulphate of cobalt and ammonia, for plating. (30960.)
- (5) Sulphate of cobalt and ammonia, crystallized in a dome. (30961.)
- (1) Sulphate of copper. Formed as a by-product in treating the ores of the Gap Mine. (30956.)

Z I N C.

ZINC MINERALS.

ZINCITE. (RED ZINC ORE.)

Composition: ZnO. Oxide of zinc, containing zinc 80.26 per cent. and oxygen 19.74 per cent.

It crystallizes in the hexagonal system, but crystals are very rare, generally occurs foliated, and varying in size from small grains to large masses. It varies in hardness from 4 to 4.5 and in specific gravity from 5.43 to 5.7. It has an adamantine luster, is dark red in color, and translucent.

Zincite occurs only in Sussex County, New Jersey, and is used largely to make zinc oxide for paints and other purposes.

To represent the occurrence of zincite two specimens are shown :

- (1) Massive, with Franklinite and willemite. Mine Hill, Franklin, Sussex County, New Jersey. (17634.)
- (2) Massive, with Franklinite and calcite. Mine Hill, Franklin, Sussex County, New Jersey. (65310.)

FRANKLINITE.

Composition : $(\text{Fe}, \text{Zn}, \text{Mn}) (\text{Fe}, \text{Mn})_2\text{O}_4$. Oxides of zinc, iron, and manganese, containing variable amounts of earth metal.

It crystallizes in the isometric system, especially in octahedrons, with modifying faces; also occurs crystalline, granular and compact. It varies in hardness from 5.5 to 6.5, and has a specific gravity of 5. It has a full metallic luster and iron-black color. It is slightly magnetic.

Franklinite is found very abundantly at and near Franklin, New Jersey, whence its name. The zinc it contains is extracted in the form of oxide for use as a paint, and afterwards the iron and manganese are smelted into spiegeleisen. To represent the occurrence of franklinite three specimens are shown :

- (1) Crystallized, in octahedrons, in calcite. Buckwheat vein, Franklin, Sussex County, New Jersey. (17636.)
- (2) Crystalline grains, in calcite. Buckwheat vein, Franklin, Sussex County, New Jersey. (65311.)
- (3) Crystalline grains, cemented by zincite. Sterling Hill, Franklin, Sussex County, New Jersey. (4802.)

SPHALERITE. (ZINC-BLENDE, BLACK JACK.)

Composition : ZnS . Sulphide of zinc, containing zinc 67 per cent. and sulphur 33 per cent.

It crystallizes in the isometric system, crystals being complicated and commonly twinned. It frequently occurs as a coating, sometimes fibrous; it also occurs massive. It varies in hardness from 3.5 to 4 and in specific gravity from 3.9 to 4.2. It has a full resinous luster and occurs in a large variety of colors, from colorless to black, the most common colors being yellow and brown. It is generally transparent, though sometimes only translucent. It has a highly characteristic dodecahedral cleavage.

Blende is a very common and abundant ore of zinc; but it is only recently that it has been much utilized, as it requires careful roasting to remove sulphur previous to the extraction of the zinc. It is generally associated with other sulphides and very frequently contains silver.

Blende yields very easily to decomposing influences, but, since the sulphate, which is apt to be formed first, is very soluble in water, the products of decomposition are generally removed as fast as formed and the zinc deposited elsewhere, generally after undergoing farther changes. Sometimes, however, it is changed directly in place to the

carbonate. To represent the occurrence of sphalerite fifteen specimens are shown :

- (1) Complicated crystals, on chert. Cowan & Bliss Mine, Lehigh, Jasper County, Missouri. (55062.)
- (2) Complicated crystals, on chert. Cowan & Bliss Mine, Lehigh, Jasper County, Missouri. (55081.)
- (3) Crystals, with roughened surfaces, on quartz. Spencer & McConey Mine, Carterville, Jasper County, Missouri. (55155.)
- (4) Complicated crystals, interior of a geode, with a little chert. Lehigh, Jasper County, Missouri. (55199.)
- (5) Complicated crystals, with a few crystals of calcite. Carterville, Jasper County, Missouri. (55204.)
- (6) Complicated crystals, with calcite and chert. Spencer & McConey Mine, Carterville, Jasper County, Missouri. (55125.)
- (7) Large complicated crystals, with small simple crystals, many of the large crystals coated with marcasite. Spencer & McConey Mine, Carterville, Jasper County, Missouri. (55122.)
- (8) Small simple crystals, on massive. Cowan & Bliss mine, Lehigh, Jasper County, Missouri. (55077.)
- (9) Separate crystals, on quartz. Spencer & McConey mine, Carterville, Jasper County, Missouri. (55154.)
- (10) Finely crystallized, on massive. Skeeterville, Lehigh, Jasper County, Missouri. (55208.)
- (11) Crystals, coated with greenockite (sulphide of cadmium). Grauby, Newton County, Missouri. (56110.)
- (12) Massive, containing a little pyrite. Friedensville, Lehigh County, Pennsylvania. (65121.)
- (13) Massive, with calcite. Buttzville, Warren County, New Jersey. (56390.)
- (14) Massive, with calcite. Oxford furnace, Warren County, New Jersey. (44187.)
- (15) Showing characteristic dodecahedral cleavage. Galena, Cherokee County, Kansas. (56210.)

WILLEMITE. (TROOSTITE.)

Composition: Zn_2SiO_4 . Silicate of zinc, containing oxide of zinc, 72.9 per cent. (zinc 58.5 per cent.), and silicic acid, 27.1 per cent.

It crystallizes in the rhombohedral system, but crystals are rare. It generally occurs massive, or disseminated in grains. Its hardness is 5.5, and specific gravity about 4. Occurs only in Sussex County, New Jersey, in sufficient amounts to constitute an ore of zinc, but quite common there. To illustrate the occurrence of willemite four specimens are shown :

- (1) Massive, brown and green, with a little Franklinite. Franklin, New Jersey. (17632.)
- (2) Massive, green, with a little Franklinite. Franklin, New Jersey. (65313.)
- (3) Massive, yellow, with a little Franklinite. Franklin, New Jersey. (17641.)
- (4) Massive, yellow and green, with a little Franklinite. Franklin, New Jersey. (65314.)

CALAMINE. (GALMEI.)

Composition: $\text{Zn}_2\text{SiO}_4 + \text{aq}$. Hydrated silicate of zinc, containing oxide of zinc 67.5 per cent. (zinc 54.2 per cent.), silicic acid 25 per cent., and water 7.5 per cent.

It crystallizes in the orthorhombic system, crystals being highly modified and generally twinned. It frequently occurs in imitative forms as a coating with fibrous structure, sometimes massive. It varies in hardness from 4.5 to 5, and in specific gravity from 3.16 to 3.9. It has a vitreous to pearly luster, and is generally white to colorless, although occasionally tinted, and transparent to translucent. On being heated gently it becomes electric.

Calamine is an abundant and valuable source of zinc. It is frequently the result of decomposition, and is generally associated with the carbonate smithsonite. To represent the occurrence of calamine, five specimens are shown:

- (1) Crystals, distinct and free at one end, but joined at the other. Granby, Newton County, Missouri. (64175.)
- (2) Crystals, distinct and free at one end, but joined at the other, pure white. Sterling Hill Mine, Franklin, Sussex County, New Jersey. (65308.)
- (3) Crystals, complicated mass of united, pure white. Sterling Hill Mine, Franklin, Sussex County, New Jersey. (65312.)
- (4) Crystals, complicated mass of united. Sterling Hill Mine, Franklin, Sussex County, New Jersey. (56386.)
- (5) Massive, stained with iron. Mossy Creek, Jefferson County, Tennessee. (55811.)

SMITHSONITE. (DRY BONE.)

Composition: ZnCO_3 . Carbonate of zinc, containing oxide of zinc 64.8 per cent. (zinc 52 per cent.), and carbonic acid 35.2 per cent.; often a part of the zinc is replaced by iron or manganese.

It crystallizes in the rhombohedral system, but crystals are very rare. Its most common occurrence is in imitative shapes, as an incrustation, or granular. Its hardness is 5, and specific gravity 4 to 4.45. It has a vitreous luster, and is generally white, though sometimes tinted, it is subtransparent to translucent.

Smithsonite is a valuable source of zinc, and is generally the result of decomposition; it is frequently associated with calamine, and sometimes with blende and galena. To illustrate the occurrence of smithsonite four specimens are shown:

- (1) Massive. Dade County, Missouri. (64153.)
- (2) Massive, milk white, slightly impure. Bertha Zinc Mine, Pulaski County, Virginia. (30648.)
- (3) Massive, with botryoidal surface. Dade County, Missouri. (64201.)
- (4) Massive, with botryoidal surface, lining cavities. Dade County, Missouri. (64156.)

ZINC ORES.

Zinc ores are divided simply into oxidized and sulphide ores. The former may contain several zinc minerals, the latter is universally blende. Owing to the fact that the first oxidation product of blende (sulphate of zinc) is soluble, it is not usual to find both characters of ores associated. Whenever blende undergoes oxidation the product is generally dissolved and removed before the zinc is deposited again.

Besides the zinc mineral specimens, all of which represent ores, the following characteristic ore specimens are shown :

Oxidized ores.

- (1) Franklinite, zincite. Franklin, Sussex County, New Jersey. (56389.)
- (2) Willemite, Franklinite, zincite. Sterling Hill, Sussex County, New Jersey. (56385.)
- (3) Calamine, crystallized. Franklin, Sussex County, New Jersey. (56388.)
- (4) Calamine, crystallized. Friedensville, Lehigh County, Pennsylvania. (10682.)
- (5) Calamine and smithsonite, colored by iron. Mossy Creek, Jefferson County, Tennessee. (55811.)
- (6) Impure calamine. Bertha Zinc Mine, Pulaski County, Virginia. (55744.)
- (7) Calamine, crystallized. Missouri. (65261.)

Sulphide ores.

- (1) Blende, crystallized. Cowan & Bliss Mine, Lehigh, Jasper County, Missouri. (55069.)
- (2) Blende and chert. Baker Diggings, Galena, Cherokee County, Kansas. (56229.)
- (3) Blende and chert. Baker Diggings, Galena, Cherokee County, Kansas. (65323.)
- (4) Blende and chert. Baker Diggings, Galena, Cherokee County, Kansas. (65324.)
- (5) Blende and chert. Oronogo, Jasper County, Missouri. (56235.)
- (6) Blende, decomposing. Granby, Newton County, Missouri. (64479.)

THE PREPARATION OF BLENDE.

THE GALENA MILL OF THE SOUTH SIDE MINING AND MANUFACTURING COMPANY.

This mill treats the ores of the Pittsburgh, Kansas district, consisting of blende, with galena and a little pyrite, in a gangue of chert. The ore is first crushed in a Blake crusher, and then in coarse rolls, after which it goes through a 7-millimetre trommel. The coarse ore from this is crushed in fine rolls, while the fine goes to a sizing trommel. The carefully sized ore is treated in a series of five 4-sieved eccentric jigs, yielding first heads, galena containing a little pyrite; second and third heads, blende; fourth heads, cherts that are crushed, and final tails to waste. The process is illustrated by the scheme figure 10.

The mill will treat 20 tons in about 10 hours, yielding 20 to 25 per cent. of dressed mineral, mostly blende.

The collection taken by Mr. J. P. Gazzam, E. M., September, 1884, shows a full series of the products.

- (1) Ore, crushed. (56173.)
- (2) Crushed ore, greater than 7 and less than 5 millimetres, fed on first sieve, first jig. (56174.)
- (3) Galena, heads, first sieve, first jig; sold. (56175.)
- (4) Blende, heads, second and third sieves, first jig; sold. (56176.)
- (5) Blende and chert, heads, fourth sieve, first jig; recrushed. (56177.)
- (6) Chert, blende, tailings, first jig. (56178.)
- (7) Crushed ore, greater than 5 and less than 3 millimetres, fed on first sieve, second jig. (56179.)

- (8) Galena, heads, first sieve, second jig; sold. (56180.)
- (9) Blende, chert, heads, second and third sieves, second jig; sold. (56181.)
- (10) Blende and chert, heads, fourth sieve, second jig; recrushed. (56182.)
- (11) Chert and blende, tails, second jig. (56183.)
- (12) Crushed ore, greater than $3\frac{1}{2}$ and less than $2\frac{1}{2}$ millimetres, fed on first sieve, third jig. (56184.)
- (13) Blende and chert, heads, second sieve, third jig; sold. (56185.)
- (14) Blende and chert, heads, fourth sieve, third jig; recrushed. (56186.)
- (15) Chert and blende, tails, third jig. (56187.)
- (16) Crushed ore less than $2\frac{1}{2}$ millimetres, fed on first sieve, fourth jig. (56189.)
- (17) Blende, heads, second sieve, fourth jig. (56191.)
- (18) Blende and chert, hutchwork, second sieve, fourth jig. (56193.)
- (19) Blende, heads, third sieve, fourth jig. (56192.)
- (20) Chert and blende, tails, fourth jig. (56190.)
- (21) Galena, heads, first sieve, fifth jig. (56188.)
- (22) Blende, heads, second sieve, fifth jig. (56194.)
- (23) Blende and chert, heads, fourth sieve, fifth jig. (56196.)
- (24) Ore, separated from mine slimes by screening. (56200.)
- (25) Blende and chert, buddle-heads, first treatment. (56197.)
- (26) Coarse sand, buddle, first treatment. (56201.)
- (27) Blende, buddle-heads, second treatment; sold. (56198.)
- (28) Tails, buddle. (56199.) —
- (29) Ore sample, all sizes. (56195.)

THE EXTRACTION OF ZINC.

There is but one universal method for extracting zinc, and that is to mix the oxidized ores, or the roasted sulphide ores, with carbon, and heat the mixture in a retort. When the proper temperature is reached, the carbon will withdraw the oxygen from the zinc and leave it in the metallic state; but the temperature at which this reaction takes place is such that the metallic zinc is volatile, and is reduced in the form of a vapor, and, therefore, after it has been reduced, it must be condensed or cooled to the liquid state. Zinc melts at 412° C., boils at 1200° C., and is reduced by carbon at 1300° C.

The retorts in which the reduction takes place may be either oval or round; they are set in brick-work furnaces, in rows, with their front ends lower than the back and opening into the air. After the charge is introduced, a suitable condenser, made of clay, is placed in the open end of the retort and attached to it. During the smelting the zinc condenses and collects in these condensers, and is withdrawn from time to time. The lower rows of retorts in the furnaces frequently get very hot, and it is necessary to use an extra sheet-iron condenser, called a "prolong." It is very difficult to condense all the zinc, and, with the utmost care, a portion of it will oxidize, and a product known as "blue powder," consisting of a mixture of oxide and metallic zinc, will be formed. In careless working this may cause very serious losses. Coal is generally used direct to heat the retorts, and the furnace is called a "Belgian furnace," but, in several cases, gas made by the Siemens process has been used successfully.

GLENDALE ZINC WORKS.

These works are situated just south of St. Louis, Missouri, on the bank of the Mississippi River. They treat a variety of ores both oxidized and sulphide. The smithsonite ore comes from Jefferson County, the calamine from Granby, Newton County, and the blende from the Joplin district. The smithsonite is calcined, the calamine is hand-dressed, and the blende crushed and jigged at the mine. The blende, as received from the separating operation, is wet; a portion of it is therefore dried and mixed hot with the remainder. It is crushed to pass an 8 mesh wire-cloth screen, and is then roasted to remove sulphur.

The roasting furnaces are two storied—that is, contain one hearth above another. As soon as the charge next to the fireplace has been completely roasted it is withdrawn from the furnace, the other charges are then moved up, and a fresh one introduced on the coldest hearth, through an opening in the roof. Every 15 or 20 minutes the ore is stirred. The six furnaces vary in size and contain charges of different weights, four charges being in each furnace all the time, two on each hearth. Roasting causes a loss of weight of about 15 per cent. of the ore. The lump calamine ore as received is first calcined in a kiln similar to a lime-kiln to remove water, four bushels of coal slack being used per ton of calamine. It is then crushed to pass a 5 mesh wire-cloth screen. The smithsonite is crushed to pass the same screen.

To reduce the zinc in the retorts slack coal from the Big Muddy vein is used on account of its low percentage of sulphur.

There are eight Belgian furnaces, built in pairs; four large ones, containing one hundred retorts in nine rows, four small ones, containing one hundred and four smaller retorts in nine rows. The closed ends of the retorts rest on shelves projecting from the wall that divides the two furnaces. The open front end is about 4 inches lower than the back and rests on $2\frac{1}{2}$ inch tile. These tiles rest on tile pillars which form the front of the furnace. After the retorts have been introduced all the openings in the front of the furnace are luted up with clay. Each furnace has a fire-place at each end, and each pair of furnaces has a common draft stack.

About 5 o'clock every morning preparations are commenced for charging the retorts. Any cracked or damaged retorts are first removed and new ones inserted, about three being replaced every 24 hours; then, commencing at the top row of retorts, the condensers are removed and cleaned. When they have been used so long that they can not be cleaned any more they are broken up. The parts containing zinc are broken off and added to the charge and the clean portions are ground up and used in making retorts. Eight new condensers are required for each furnace every 24 hours.

After the condensers are removed the residues remaining in the retorts are raked out and the retorts cleaned, when they are ready for charging. The charge has been made up on the day before. For the

large furnace it consists of 3,600 pounds of roasted blende, 600 pounds of calamine, 600 pounds of smithsonite, and 20 to 25 bushels of coal.

The coal is spread upon the floor, upon this is spread the smithsonite and calamine, and then the hot blende is spread over all. The pile is wet down, thoroughly mixed with shovels, and left till the next morning. The blue powder and dross from the previous charge is mixed with 300 pounds of calamine and 4 bushels of coal and charged into the upper rows, while the chippings from the condensers are added to the regular charge for the fifth and sixth rows.

About 6 a. m. the charging begins at the upper row of retorts. The charge is introduced by means of a semicircular shovel, and as soon as the retort is full a round bar of iron is forced through it near the top in order to assist the exit of the zinc. The condenser is then adjusted. The charging is finished between 9 and 11 a. m., and immediately the zinc is withdrawn from the condensers of the upper rows. It is drawn from the whole furnace at 4 p. m., 8 p. m. and again about 4 o'clock the next morning. The zinc is drawn into a ladle, skimmed and cast into slabs.

The large furnaces produce from 2,400 to 2,600 pounds of spelter per 24 hours, and about 150 bushels of common Illinois slack coal is used for heating.

The collection, taken by Mr. J. P. Gazzam, E. M., September, 1884, shows a full series of the ores, the fuels, and the products.

Ore.

- (1) Blende No. 1, lump ore. (54561.)
- (2) Blende No. 1, jigged ore. (54558.)
- (3) Blende No. 2, lump ore. (54567.)
- (4) Blende No. 2, fine ore. (54568.)
- (5) Blende, containing a little chert, No. 3, fine ore. (54569.)
- (6) Blende, a mixture of different jigged ores, ready to be roasted. (54549.)
- (7) Roasted blende. (54553.)
- (8) Mixed roasted blende, ready to be charged into the retorts. (54550.)
- (9) Calcined smithsonite. (54560.)
- (10) Calcined smithsonite, crushed, ready to be charged into the retorts. (54556.)
- (11) Calamine, lump ore. (54562.)
- (12) Calamine, calcined. (54559.)
- (13) Calamine, crushed. (54557.)

Fuel.

- (1) Coal slack, from Big Muddy vein; used in retorts. (54552.)
- (2) Coal slack, crushed, to be mixed with the ore to reduce the zinc in the retorts. (54551.)
- (3) Coal slack, used for fuel; from Illinois. (54555.)

Product.

- (1) Metallic zinc or spelter, ordinary. (54565.)
- (2) Metallic zinc or spelter, ordinary; broken to show fracture. (54563.)
- (3) Metallic zinc or spelter, refined. (54566.)
- (4) Metallic zinc or spelter, refined; broken to show fracture. (54564.)
- (5) Blue powder, a mixture of oxide and metallic zinc from condensers. (54570.)
- (6) Blue powder, a mixture of oxide and metallic zinc taken from the flues. (54554.)

THE JOPLIN ZINC COMPANY.

These works are located at West Joplin, Jasper County, Missouri, and treat the ores of the neighboring regions, principally the separated blende from Galena, Cherokee County, Kansas. The ore is divided into two grades and they are mixed in about equal proportions. A portion of the wet ore as received is dried and the hot dry ore mixed with wet ore, the total loss in drying being about 5 per cent. The coarse ores are crushed to pass through a six-mesh wire-cloth screen.

There are eight two-storied roasting furnaces, built in two blocks. Each furnace is charged every 8 hours with 1,300 pounds of raw ore, producing 1,100 pounds of roasted ore. The four Belgian furnaces contain 112 retorts in eight rows. Each furnace is charged every 24 hours with 5,100 pounds of roasted ore and 50 bushels of coke and produces 2,200 to 2,300 pounds of spelter.

The collection taken by Mr. J. P. Gazzam, E. M., October, 1884, shows a full series of the raw and roasted ores, the fuels, and the products.

Ore.

- (1) No. 1 blende, separated from the ore by crushing and jigging. Value, \$17 per ton. (55222.)
- (2) No. 2 blende, carrying a little chert, separated from the ore by crushing and jigging. Value, \$13 per ton. (55223.)
- (3) Blende, carrying a little chert; the mixed ore ready for the roaster. (55227.)
- (4) Roasted mixed blende. (55228.)
- (5) Roasted mixed blende, ready for retorts. (55229.)

Fuel.

- (1) Bituminous coal, used for heating the zinc retorts; from Stilson, Kansas. (55224.)
- (2) Coke, used in the retorts to reduce the zinc. (55225.)
- (3) Coke, used in the retorts to reduce the zinc; crushed ready for charging. (55226.)

Products.

- (1) Metallic zinc or spelter. (55235.)
- (2) Metallic zinc or spelter, showing fracture. (55236.)
- (3) Blue powder, a mixture of oxide of zinc and metallic zinc resulting from imperfect condensation. From condensers. (55231.)
- (4) Blue powder, a mixture of oxide of zinc and metallic zinc, from pulverizers. (55230.)
- (5) Residue, from the retorts after the extraction of the zinc. (55232.)

Accessories.

- (1) Fire clay, used for the manufacture of retorts. (55233.)
- (2) Cement, mixed fire clay and old retorts ground together, used for setting retorts. (55234.)
- (3) Ashes, used for dusting condenser mold to prevent sticking. (55278.)

RICH HILL ZINC WORKS.

These works are located at Rich Hill, Jasper County, Missouri, and smelt ores from Joplin. They are located in a coal region where fuel is abundant. The works contain a kiln for drying the ore, three furnaces for roasting, one Belgian and one Siemens smelting furnace. The ores treated are the first and second class blende separated from the Joplin, Missouri, ores, together with some lump ore. The ore as received from the separating operation is generally wet, and one-third of it is dried in the small reverberatory furnace, and mixed hot with two-thirds of the wet ore, the mixture being dry enough for further treatment.

The coarse ores are crushed in a rock breaker, and then in rolls. The fine ore is crushed in the rolls only. The crushed ore is roasted in two-storied reverberatory furnaces having four hearths, to remove the sulphur. A charge weighing 1,400 pounds is put in the furnaces every 12 hours through openings in the roof, and remains on each hearth 12 hours, during which time it is stirred every 10 to 20 minutes. In 48 hours it is withdrawn from the lower hearth nearest the fireplace. The charge loses, on roasting, about 15 per cent. of its weight.

The roasted ore is mixed with coal slack and coke. After the ore and coal are mixed, they are slightly dampened, and charged into the retorts by means of a round shovel or scoop. After the retort is full, a half-inch bar of iron is pushed through the upper part of the charge and then withdrawn, in order to leave a channel to aid the exit of the zinc.

The Belgian furnace is built after the usual pattern with two divisions having a fireplace at each end, and a common chimney. Each side has seven rows of retorts with fourteen in a row. The three lower rows of retorts, where the heat is greatest, are charged twice in 24 hours, while the others are charged only once. In the upper two rows blue powder and other refuse from former smeltings are charged.

The metal is withdrawn from the lower three rows of condensers six times in 24 hours, and from the others four times. This furnace will treat about 10,000 pounds of ore in 24 hours.

The Siemens gas furnace consists of two retort chambers built upon long and narrow reheating chambers, and separated from each other by a thick firebrick wall; the back ends of the retorts rest upon this dividing wall. There are three rows of forty-eight retorts each in each chamber, and the furnace will treat 1,600 pounds of ore per 24 hours. The great advantage of this furnace is the greater uniformity and better control of the heat, by which means poorer ores may be smelted. In this case second-class ores are treated very successfully.

The collection taken by Mr. E. L. Zukoski, E. M., October, 1884, shows the ore, fuels, charges, products, and a few accessories.

Ore.

(1) Blende, with some chert, crushed ready for the roasters. (55421.)

(2) Roasted blende, ready to be charged into the retorts. (55422.)

Fuel.

- (1) Coal slack. (55432.)
- (2) Coke, manufactured from coal slack in beehive ovens. (55424.)
- (3) Crushed coke and coal slack, two-thirds coke and one third slack; used to reduce the zinc from the ore in the retorts. (55425.)

Charge.

- (1) Retort charge, used in upper two rows of retorts of the Belgian furnace; consists of roasted ore, blue powder, scrapings from condensers, coke, and slack. (55433.)
- (2) Retort charge, used in lower rows of retorts of the Belgian furnace; consists of roasted ore, coke, and slack. (55438.)

Product.

- (1) Spelter or metallic zinc. (55435.)
- (2) Spelter or metallic zinc, showing fracture. (55436.)
- (3) Blue powder, a mixture of oxide and metallic zinc, resulting from imperfect condensation. (55437.)
- (4) Residue, remaining in the lower retorts of the Belgian furnace after the extraction of the zinc. (55434.)
- (5) Flue dust, consisting largely of oxide of zinc. From the reheating chambers of the gas furnace. (55426.)
- (6) Flue dust, containing oxide of zinc from the flues of the roaster. (55427.)
- (7) Slag accretion, formed in the bottom of the gas furnace. (55431.)

Accessories.

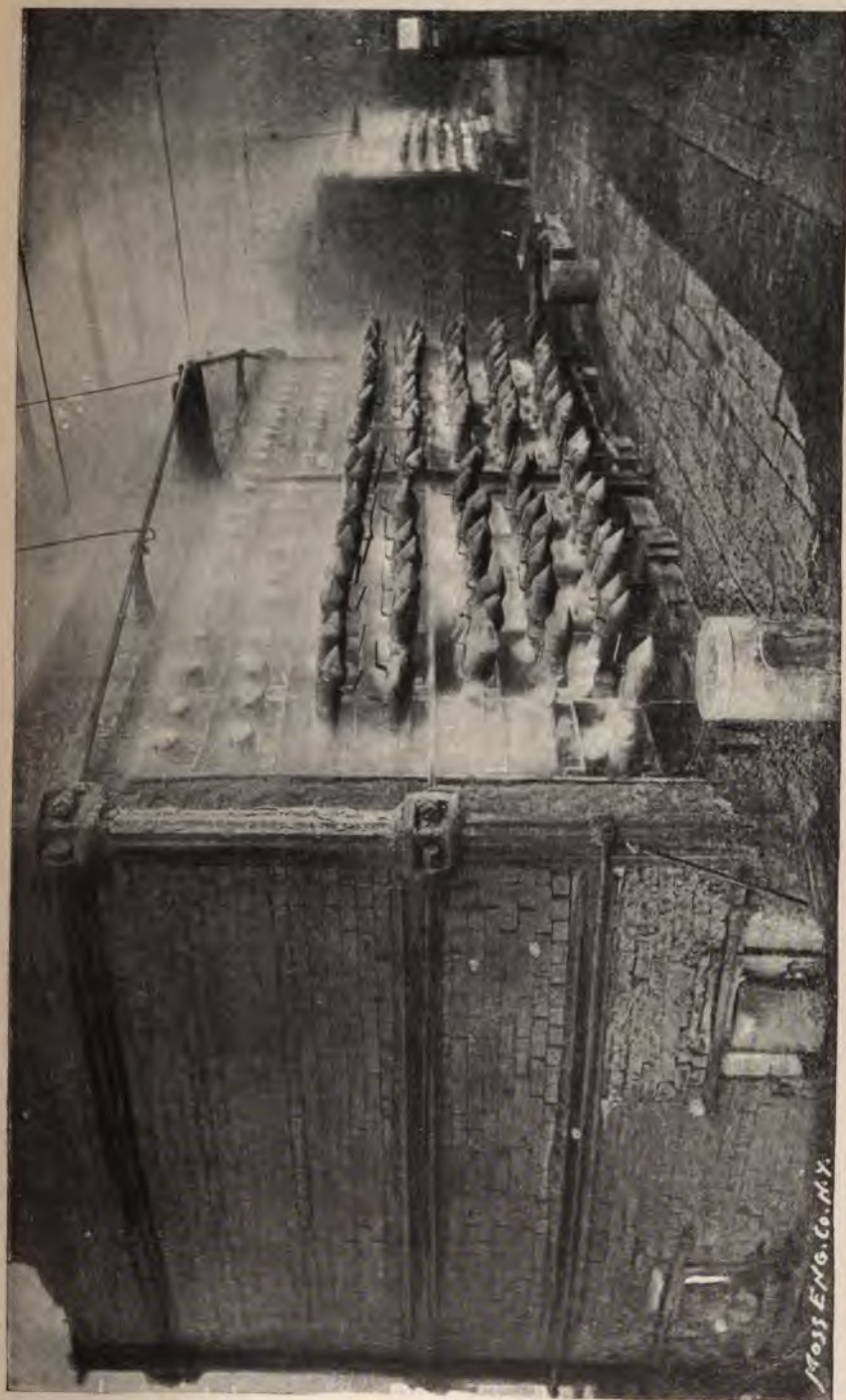
- (1) Clay, a mixture for manufacturing retorts. (55423.)
- (2) Retort, in use one week. (55428.)
- (3) Retort, in use one month. (55429.)
- (4) Retort, with accretions on bottom, in use two months. (55430.)

PASSAIC ZINC WORKS.

These works are situated at La Fayette, near Jersey City, New Jersey. They were started in 1854, when furnaces for the production of oxide of zinc from the Franklinite ores were built. In 1875 Belgian furnaces for the production of spelter from the silicate and carbonate ores were added, and in 1884 a shaft furnace for smelting spiegeleisen from the residues from the oxide furnaces containing iron and manganese was added.

The ores used are mined at Sterling Hill, Ogdensburgh, and Mine Hill, Franklin, Sussex County, New Jersey, and are divided into silicate and carbonate ores, and Franklinite ores. The former are used for the production of spelter, but the latter can not be, since the silicate of manganese formed from the manganese in the ore is very destructive to the retorts on account of its easy fusibility. The Franklinite ore is very complex, containing Franklinite, zincite, willemite, and rhodonite, in varying proportions, in a gangue of calcite.

The spelter furnaces are built in three blocks of four each, eight large, and four small. The large furnaces contain seven rows of retorts



BELGIAN ZINC FURNACES, PASSAIC ZINC COMPANY, JERSEY CITY, NEW JERSEY.
(See explanation, page XVI.)

Moss Eng. Co. N.Y.

with ten in a row. The usual charge consists of 32 to 39 pounds of ore mixed with 21 pounds of anthracite coal dust.

The oxide furnaces commonly known as Wetherill furnaces are simply rectangular furnaces 6 feet by 4 feet, with an arched roof 3 to 4 feet above the grate which consists of perforated iron slabs. There are forty-eight of these furnaces.

The Franklinite ore is mixed with anthracite coal dust, and charged into these furnaces, the metallic zinc is reduced in the form of vapor, and, an excess of air being admitted above the fire, it is immediately converted into oxide of zinc in a very fine state of subdivision. An exhaust fan draws this oxide of zinc suspended in air through cooling tubes, and delivers it to a large number of cotton bags which allow the air to pass through, but retain the oxide of zinc. From time to time the oxide of zinc is removed from the collecting apparatus in the form of an impalpable white powder which is used for a white paint.

The residuum remaining in the oxide furnace is drawn off and sent to the spiegel furnace. The spiegel furnace is an ordinary blast furnace, 37½ feet by 8 feet, which is run in the same manner as an ordinary iron furnace, but with special provisions for collecting the zinc which remains in the residuum, and is driven off during the smelting in the form of oxide, and then collects in the gas ways. Greater care is also necessary in order to keep the furnace running smoothly. The ordinary charge for this furnace is 1,150 pounds of residuum, 1,000 pounds of anthracite coal, 270 pounds of limestone. Fifty to sixty of these charges are made daily, producing about 10 tons of about 20 per cent. spiegel. There are also made about 13 tons of oxide of zinc per week, which is smelted in the spelter furnaces.

A block of the Belgian furnaces is shown in PL. XXIII and the oxide furnaces in PL. XXIV.

The collection taken by Mr. J. B. Mackintosh, E. M., October, 1884, represents a large series of the Franklin ores, the fuel, the intermediate, and final products.

SPELTER FURNACE SAMPLES.

Ore.

- (1) Calamine, showing decomposition. Ogdensburg, Sussex County, New Jersey. (54133.)
- (2) Calcined silicate, lump ore. (54134.)
- (3) Calcined silicate, crushed, ready for furnaces. (54135.)

Furnace Charge.

- (1) Ore, mixed with anthracite coal dust. (55834.)

Products.

- (1) Spelter or metallic zinc. (54142.)
- (2) Blue powder, a mixture of metallic zinc and oxide of zinc, obtained as a by-product in distilling zinc. (54141.)
- (3) Residue, remaining in the retorts after reducing and distilling the metallic zinc from the silicate ore. (54143.)

Accessories.

- (1) Fire clay. Woodbridge, Middlesex County, New Jersey. (55827.)
- (2) Sandy clay. Woodbridge, Middlesex County, New Jersey. (55828.)
- (3) Burnt clay. (55829.)
- (4) Quartz sand. (55830.)
- (5) Retort, old. (55831.)
- (6) Retort, old, ground. (55832.)
- (7) Retort, new. (55833.)

*OXIDE FURNACE SAMPLES.**Ore.*

- (1) Franklinite, willemite, zincite, and calcite, lump ore. Buckwheat Field Mine-Franklin, Sussex County, New Jersey. (54129.)
- (2) Franklinite, willemite, zincite, and calcite, crushed, ready for furnaces. Buck, wheat Field Mine, Franklin, Sussex County, New Jersey. (54130.)

This ore yielded on analysis in the laboratory of the department by Mr. J. A. Allen—

	Per cent.
Silica (SiO_2)	10.88
Zinc (Zn)	29.86
Manganese (Mn)	11.19
Iron (Fe)	20.97
Alumina (Al_2O_3)	0.82
Lime (CaO)	4.50
Magnesia (MgO)	0.39
Carbonic acid (CO_2)	3.93

- (3) Franklinite, willemite, zincite, tephroite, and calcite, lump ore. Sterling Hill Mine, Ogdensburgh, Sussex County, New Jersey. (54131.)

- (4) Franklinite, willemite, zincite, tephroite, and calcite, crushed, ready for furnaces. Sterling Hill Mine, Ogdensburgh, Sussex County, New Jersey. (54132.)

This ore yielded on analyses in the laboratory of the Department by Mr. J. A. Allen—

	Per cent.
Silica (SiO_2)	7.80
Zinc (Zn)	19.80
Manganese (Mn)	8.89
Iron (Fe)	16.44
Alumina (Al_2O_3)	1.09
Lime (CaO)	15.91
Magnesia (MgO)	2.08
Carbonic acid (CO_2)	14.11

Fuel.

- (1) Anthracite coal. (54136.)
- (2) Anthracite coal dust, used for reducing the zinc in the retorts and oxide furnaces. (54137.)

Furnace charge.

- (1) Ore, mixed with anthracite coal dust. (55835.)

Products.

- (1) Oxide of zinc, obtained from Franklinite ore by smelting with coal dust and reoxidizing the distilled zinc; it is afterward cooled and collected in muslin bags. (54140.)



ZINC OXIDE FURNACES, PASSAIC ZINC COMPANY, JERSEY CITY, NEW JERSEY.
(See explanation, page XVI.)

(2) Residuum, remaining in the oxide furnaces after the extraction of the zinc, contains iron and manganese, which are extracted in a blast furnace as spiegeleisen. (54138.)

(3) Residuum, from oxide furnaces, showing crystallized oxide of zinc. (54139.)

SPIEGEL FURNACE SAMPLES.

(1) Residuum, the residue after the extraction of the zinc from Franklinite ore in the zinc oxide furnace. It contains the iron and manganese of the ore. (54965.)

(2) Coal, anthracite coal used for fuel. (54966.)

(3) Limestone, calcite, containing a little pyrite; used for flux. From Sing Sing, Westchester County, New York. (54967.)

(4) Slag. (54964.)

(5) Graphite, carbon, in spiegel slag. (54963.)

(6) Spiegeleisen, an alloy of iron and manganese, rich in combined carbon; used in the manufacture of steel. (54968.)

(7) Zinc oxide, from the gas ways. (54969.)

T I N.

TIN MINERAL.

CASSITERITE. (TIN STONE, STREAM TIN.)

Composition: SnO_2 . Oxide of tin, containing tin 78.67 per cent. and oxygen 21.33 per cent.

It crystallizes in the tetragonal system, crystals being very complex and generally twinned. It sometimes occurs in globular form with fibrous structure, and also massive. It varies in hardness from 6 to 7 and in specific gravity from 6.4 to 7.1. Its general color is brown, but it occurs of several shades of red and gray, also white. Sometimes it is nearly transparent, and graduates into opaque.

Cassiterite is the universal tin ore and can readily be distinguished from most minerals with which it could be confounded by its high specific gravity. It is represented by a single specimen here. Others will be found with the tin ores.

(1) Rough crystals. Irish Creek, Rockbridge County, Virginia. (30866.)

TIN ORES.

It has been generally supposed that tin was a rare metal in this country. This, however, is only partially true, the occurrence of cassiterite, the binoxide of tin, in small quantities, being known to mineralogists from a large extent of territory for many years; but it is only in very rare instances that this occurrence has given even the slightest evidence of there being a deposit which would prove of any commercial value. The first discovery that was at all favorable was made by Professor Jackson in New Hampshire in 1840. Specimens of this ore, together with a bar of tin produced, have been in the Museum many years.

A small amount of cassiterite from two localities, together with a bar of the tin produced, from Montana, was exhibited at the Centennial. An ore of a different character, being a stanniferous wolfram, has been known in California for many years, and at one time, quite extensive operations were commenced upon the deposit. The ore, however, is somewhat difficult of treatment, and this, with litigation, soon closed up the mine and the works. Isolated specimens of cassiterite have been found at various times from several localities in Maine, and the next discovery of any importance was at Winslow, in that State, where a more definite vein carrying cassiterite was discovered in 1867. The vein here, however, was exceedingly small and nothing has been accomplished. Following close upon each other, in 1882-'83, there were discoveries of tin in three widely separated localities, which have given promise of ultimately producing more or less tin. These localities are at the Broad Arrow Mines, in Alabama; the Cash Mines, in Rockbridge County, Virginia, and the deposits at Harney Peak, in the Black Hills of Dakota. In 1884 a further discovery was made at King's Mountain, North Carolina.

The collection of tin ores, besides including a few specimens of purely mineralogical significance, contains samples of every locality that has ever given any promise of producing the ore in any amount.

- (1) Cassiterite, fluorite, margarite, calcite, shows full width of the vein. Winslow, Kennebec County, Maine. (4785.)
- (2) Cassiterite, in mica and quartz. Peru, Oxford County, Maine. (54215.)
- (3) Cassiterite, in feldspar, with quartz and tourmaline. Norway, Oxford County, Maine. (54216.)
- (4) Cassiterite, in feldspar, with quartz and tourmaline. Rumford, Oxford County, Maine. (54214.)
- (5) Cassiterite, crystalline. Paris, Oxford County, Maine. (54213.)
- (6) Cassiterite, in schist, discovered in 1840. Jackson, Carroll County, New Hampshire. (13397.)
- (7) Metallic tin, smelted in 1840 from the Jackson ores. (33617.)
- (8) Cassiterite, in coarse granite, called "greissen." Black Hills, Dakota. (56546.)
- (9) Cassiterite, in coarse granite, called "greissen." Etta Mine, Rapid City, Pennington County, Dakota. (65148.)
- (10) Cassiterite, in quartz. Width of vein 35 feet. Etta Mine, Pennington County, Dakota. (56547.)
- (11) Cassiterite, in rough crystals and water-worn fragments, with other heavy minerals. Black Hills, Dakota. (56548.)
- (12) Metallic tin, some of the first metal smelted from the Black Hills ores. (51213.)
- (13) Cassiterite, in rough crystals and water-worn fragments, with other heavy minerals. Bear Gulch district, Lawrence County, Dakota. (33356.)
- (14) Cassiterite, in water-worn pebbles, stream tin. Ten Mile district, Lewis and Clarke County, Montana. (10922.)
- (15) Cassiterite, in water-worn pebbles, stream tin. Prickly Pear, Jefferson County, Montana. (11044.)
- (16) Metallic tin, from the Prickly Pear ores, Montana. (29909.)
- (17) Cassiterite, characteristic sample of the Temescal ore. Temescal, San Bernardino County, California. (56423.)
- (18) Stanniferous wolfram. San Jacinto Mine, Temescal, San Bernardino County, California. (16097.)

- (19) Metallic tin, smelted from the San Jacinto ores. (16096.)
- (20) Cassiterite, with a little quartz, showing full width of vein. Cash Mine, Rockbridge County, Virginia. (30921.)
- (21) Cassiterite, in quartz. Martha D. Cash Mine, No. 2, Rockbridge County, Virginia. (43997.)
- (22) Quartz gangue. Martha D. Cash Mine, No. 2, Rockbridge County, Virginia. (43999.)
- (23) Cassiterite, crystallized in gneiss. Martha D. Cash Mine, No. 1, Rockbridge County, Virginia. (43998.)
- (24) Metallic tin, smelted from the ores of the Cash Mines. (55405.)
- (25) Cassiterite, rough crystals and water-worn fragments, stream tin. King's Mountain, Cleveland County, North Carolina. (57775.)
- (26) Cassiterite, rough crystals and water-worn fragments, stream tin. King's Mountain, Cleveland County, North Carolina. (54217.)
- (27) Cassiterite, water-worn fragments, stream tin. Broad Arrow Mine, Ashland district, Clay County, Alabama. (34168.)
- (28) Stanniferous hematite. Broad Arrow Mine, Ashland district, Clay County, Alabama. (34169.)
- (29) Gneiss rock, carrying disseminated cassiterite, contains about 2 per cent. of tin. Broad Arrow Mine, Ashland district, Clay County, Alabama. (34172.)
- (30) Metallic tin, smelted from the Broad Arrow ores. (34173.)

ANTIMONY.

ANTIMONY MINERAL AND ORE.

STIBNITE.

Composition: Sb_2S_3 . Sulphide of antimony, containing antimony 71.8 per cent. and sulphur 28.2 per cent.

It crystallizes in the orthorhombic system, crystals being long-bladed and complex. It generally occurs columnar massive. Its hardness is 2 and its specific gravity is 4.5; it has a lead-gray color and full metallic luster; it can be cut into shavings with a knife.

Stibnite is the universal antimony ore, and is illustrated by seven specimens:

- (1) Crystallized and massive, with a little quartz. San Benito County, California. (56408.)
- (2) Massive, fibrous, with quartz. Summit Mine, San Emigdio mining district, Kern County, California. (34294.)
- (3) Massive, fibrous. Humboldt County, Nevada. (56469.)
- (4) Massive, fibrous, a little decomposed. American Antimony Mine, Utah. (55369.)
- (5) Fibrous, separated. American Antimony Mine, Utah. (55370.)
- (6) Metallic antimony, from the American mine ores. (55373.)
- (7) Massive, fibrous, with quartz and calcite. Silver Hill, Sevier County, Arkansas. (56402.)

MERCURY.

MERCURY MINERALS.

MERCURY. (QUICKSILVER.)

Composition: Pure mercury. Occurs in small fluid globules scattered through a gangue. Free mercury is not common, but is found in small amounts in a number of mines, and is illustrated by a single specimen here. Six other specimens showing free mercury are included in the ore and the New Almaden collections.

(1) Free mercury globules, with cinnabar in quartz. Rattlesnake Mine, Sonoma County, California. (15936.)

CINNABAR.

Composition: HgS . Sulphide of mercury, containing mercury 86.2 per cent. and sulphur 13.8 per cent.

It crystallizes in the rhombohedral system, crystals being very complex and not common; it generally occurs granular and massive. It varies in hardness from 2 to 2.5; its specific gravity is 8.99. It is cochineal red in color, has an adamantine luster, and is subtransparent to opaque. Cinnabar is the universal mercury ore, and is illustrated by four specimens:

(1) Crystallized, cementing a quartz conglomerate. Phoenix Mine, Pope Valley, Napa County, California. (15985.)

(2) Crystalline, botryoidal mass overlaid by chalcedony. Phoenix Mine, Pope Valley, Napa County, California. (65315.)

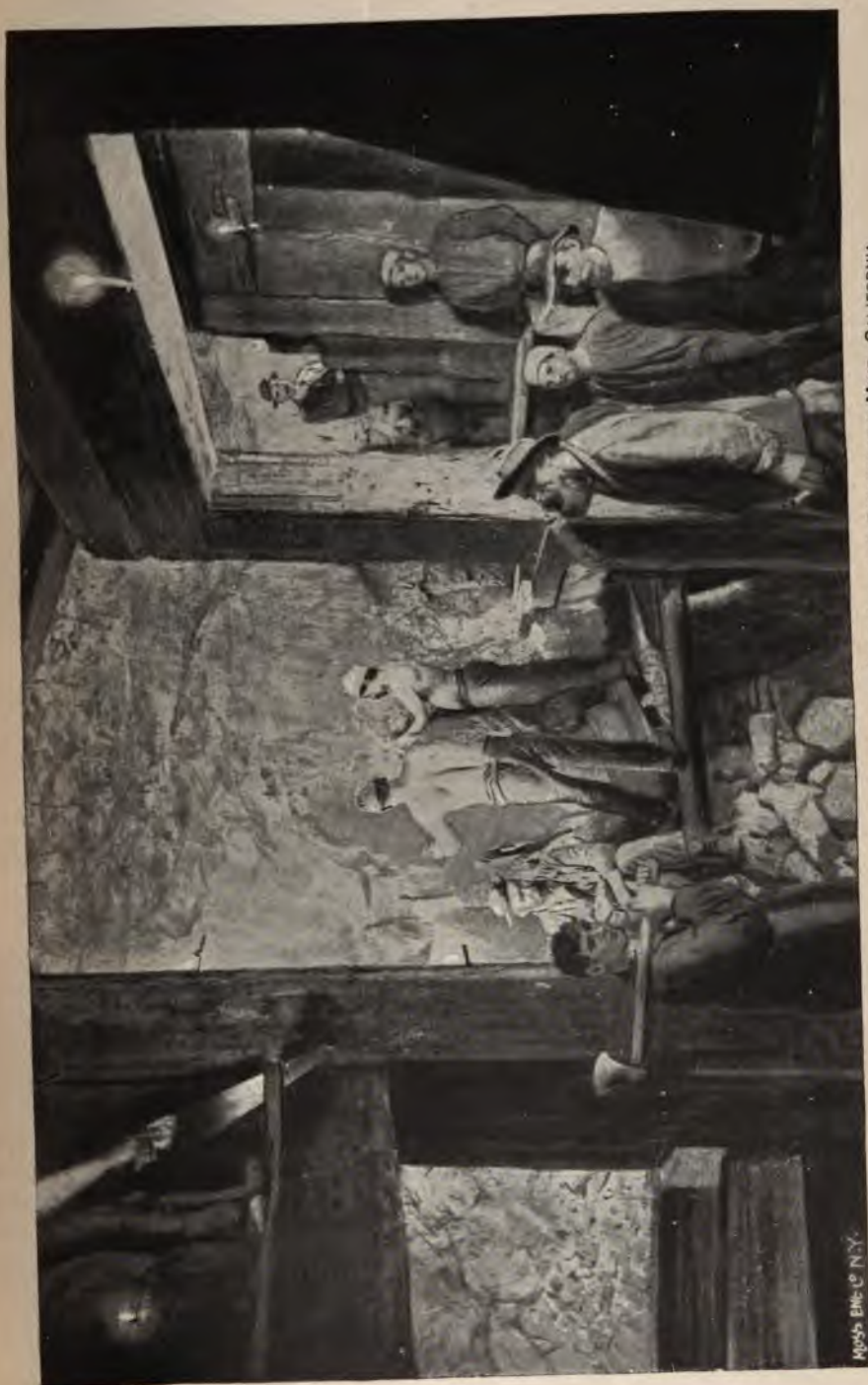
(3) Massive, with layers of quartz. Pomposa Mine, Santa Barbara County, California. (56420.)

(4) Crystalline and massive. New Hope Mine, Fresno County, California. (15083.)

MERCURY ORES.

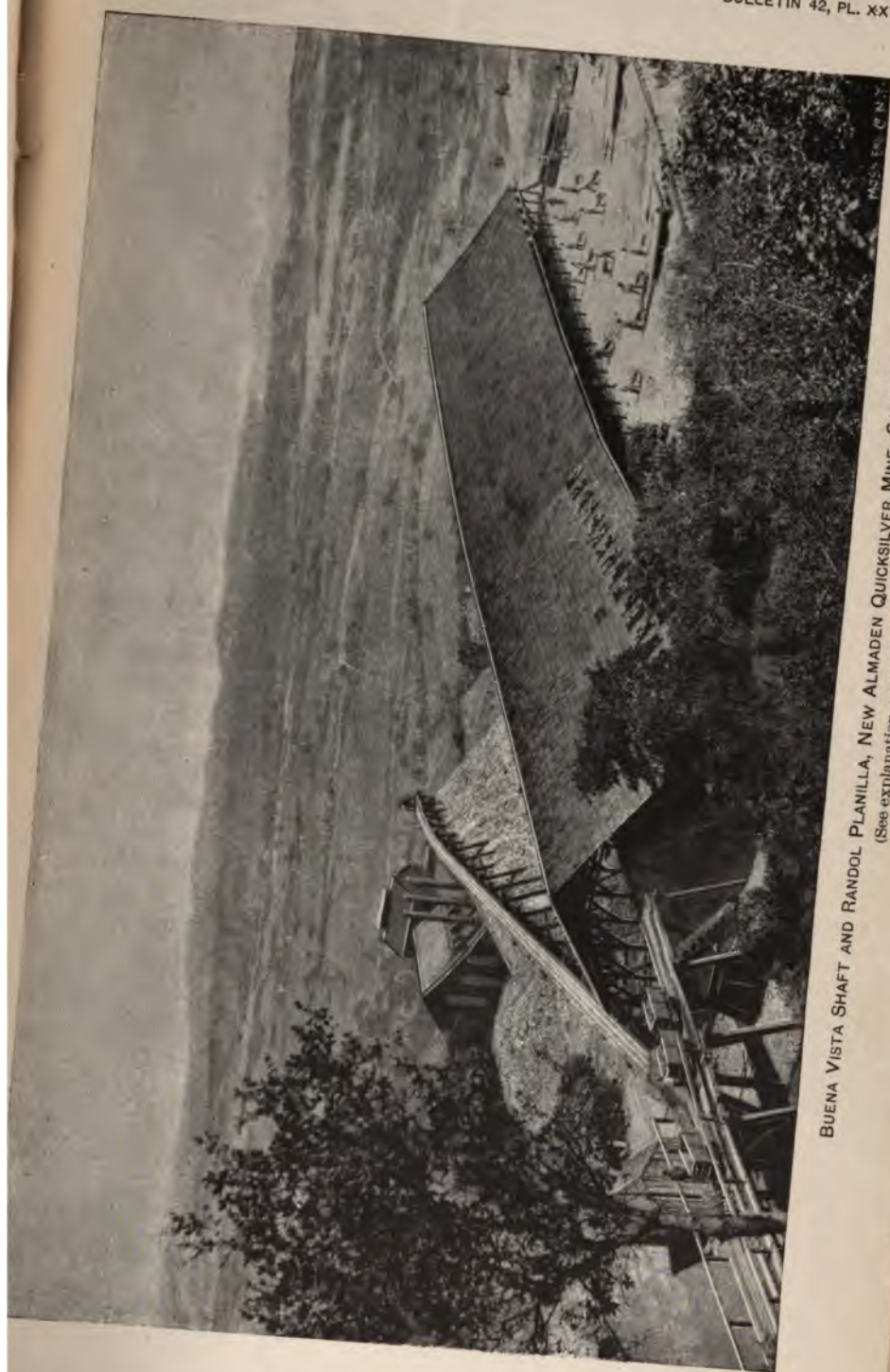
For the extraction of the metal mercury ores are roasted, by which treatment the combination between the mercury and sulphur is broken up and the mercury is set free. This roasting is carried on above the boiling point of the metal, and it is therefore volatilized with the products of combustion. The products of combustion are conducted through condensers, where the mercury collects and is drawn off. Mercury, on account of the fact that it is fluid at ordinary temperatures, occupies a unique position among the metals. Moreover, its extensive use in extracting the precious metals, for which enormous quantities are used, makes it doubly interesting and valuable to the metallurgist.

While specimens of cinnabar occur in many localities, yet the production of mercury is mainly confined to three localities: Almaden in Spain; California, especially New Almaden, and Idria in Austria.



Moss & Co. N.Y.

LABOR OR WORKING SPACE ON 1500-FOOT LEVEL, NEW ALMADEN QUICKSILVER MINE, CALIFORNIA.
(See explanation, page XVII.)



BUENA VISTA SHAFT AND RANDOL PLANILLA, NEW ALMADEN QUICKSILVER MINE, CALIFORNIA.
(See explanation, page XVII.)

MASS. EX. & N.Y.

Eight specimens illustrate the subject here, and a complete collection from New Almaden is shown further on :

- (1) Free mercury, cinnabar, and quartz. American Mine, Lake County, California. (15118.)
- (2) Cinnabar and quartz. Georgia Mine, Sonoma County, California. (15074.)
- (3) Cinnabar and quartz. Oakland Mine, Sonoma County, California. (15122.)
- (4) Cinnabar and quartz. Geyser Mine, Sonoma County, California. (15979.)
- (5) Cinnabar and quartz. Geyser Mine, Sonoma County, California. (65316.)
- (6) Cinnabar and quartz. Washoe County, Nevada. (56470.)
- (7) Mercury, distilled from California cinnabar. (34301.)
- (8) Iron flask, in which mercury is transported. Holds 76½ pounds of mercury. (29912.)

NEW ALMADEN MINES AND WORKS.

The quicksilver mines and reduction works of New Almaden are 15 miles south of the city of San José, Santa Clara County, California, in the Santa Cruz Mountains, at an elevation of 1,700 feet above the sea. These mines were first worked for quicksilver in 1845, but the operations were on a small scale, and no record exists earlier than 1850. They have been, and now are, the most productive quicksilver mines in the world, except the mines at Almaden, Spain. They are developed to the depth of 2,300 feet, and the workings extend horizontally over 1 mile square.

About 500 men find steady employment, the work being actively prosecuted throughout the year. From the 1st of January, 1864, to the 31st of December, 1887, the number of feet of drifting and sinking amounted to 224,922 feet, or 42.60 miles, at a cost of \$1,918,457.29. This does not include the excavations made in extracting ore. For the ground opened up during the previous period, from 1850 to 1864, 15 miles of drifting and sinking can be added.

The reduction works consist of eight furnaces and include the most improved methods for working quicksilver ores. They may be considered as one of the most complete and perfect in every respect in the world. In the early days the ores were very rich, averaging 30 per cent. and more of quicksilver, and the amount of ore extracted was comparatively small. The ores have gradually grown poorer, and now the percentage of mercury is about 2. In order to keep up the production of metal large amounts of ore have to be extracted.

In the first full year of which there is a record, July, 1850, to June 30, 1857, 4,970,717 pounds of ore, averaging 36.74 per cent. of mercury, yielded 23,875 flasks, while in the year 1887, 64,151,300 pounds of ore, averaging 2.38 per cent. mercury, yielded 20,000 flasks. The total production to the end of 1887 has been 862,788 flasks, weighing 76½ pounds each.

The collection from the mine includes a full series of characteristic ores, the vein filling, and the wall rocks, together with an excellent glass model of the mine. The operation of the reduction furnaces is fully illustrated by 11 specimens. To the specimens are added an ex-

cellent series of photographs of characteristic scenes about the works and mine, both above and below ground.

A working space 1,500 feet below ground is shown in PL. XXV, a view of a shaft house and dressing floor in PL. XXVI, a general view of the reduction works in PL. XXVII, and a view of a furnace in PL. XXVIII.

(1) Hanging wall, or "alta," as it is called, from the Spanish word meaning high. This invariably forms one of the boundary walls of the ore-bearing vein, the line of contact of the two being usually very distinct. The physical properties of the rock are well represented in the specimen, although its color and hardness vary considerably. It is usually black, but is sometimes white, gray, brown, or yellow, the last color being characteristic of surface "alta." It is sometimes found in the form of clay, at others it is slate or shale and harder and more tenacious than the specimen. (66436.)

Nos. 66437 to 66454 inclusive are characteristic specimens of ore and veinstone from the main ore chute.

(1) Nearly pure cinnabar, from the 1,500-foot level. Large bodies of this quality of ore are frequently found. (66437.)

(2) Cinnabar, mixed with its characteristic gangue, consisting principally of dolomite, talc, calcite, and bitumen. These specimens are typical, the bulk of the ore taken from the mine being found in this condition. (66438, 66439, and 66440.)

(3) Globules of native mercury, in characteristic gangue. Specimens of this kind are very common, but the yield of quicksilver from them is small. (66441.)

(4) Globules of native mercury, in characteristic gangue shows especially cavities containing bitumen. (66442.)

(5) Globules of native mercury, in characteristic gangue. A very handsome specimen, showing large globules on crystallized dolomite. (66443.)

(6) Crystals of cinnabar, which are sometimes found with a few globules of free mercury in cavities. (66444.)

(7) Cinnabar, very handsomely crystallized. (66445.)

(8) Dolomitic veinstone, often found in large slabs. Scored and polished naturally. (66446.)

(9) Dolomitic veinstone, well crystallized. Occurs in seams and cavities, intermixed with other vein matter and ore. (66447.)

(10) Dolomitic veinstone. Contains more of the carbonates of iron and calcium than is common. (66448.)

(11) Veinstone, from old workings near the surface. The vein from this part of the mine differs from that of the lower levels in its color, and in its being intermixed, more or less, with the hanging wall material. (66449 and 66450.)

(12) Veinstone, from the surface, in the vicinity of the place where cinnabar was first discovered. (66451.)

(13) Vein rock, from a "labor" or working space on the 1,800-foot level. Contrary to the usual condition in productive vein rock, considerable free mercury and very little cinnabar are found here. (66452.)

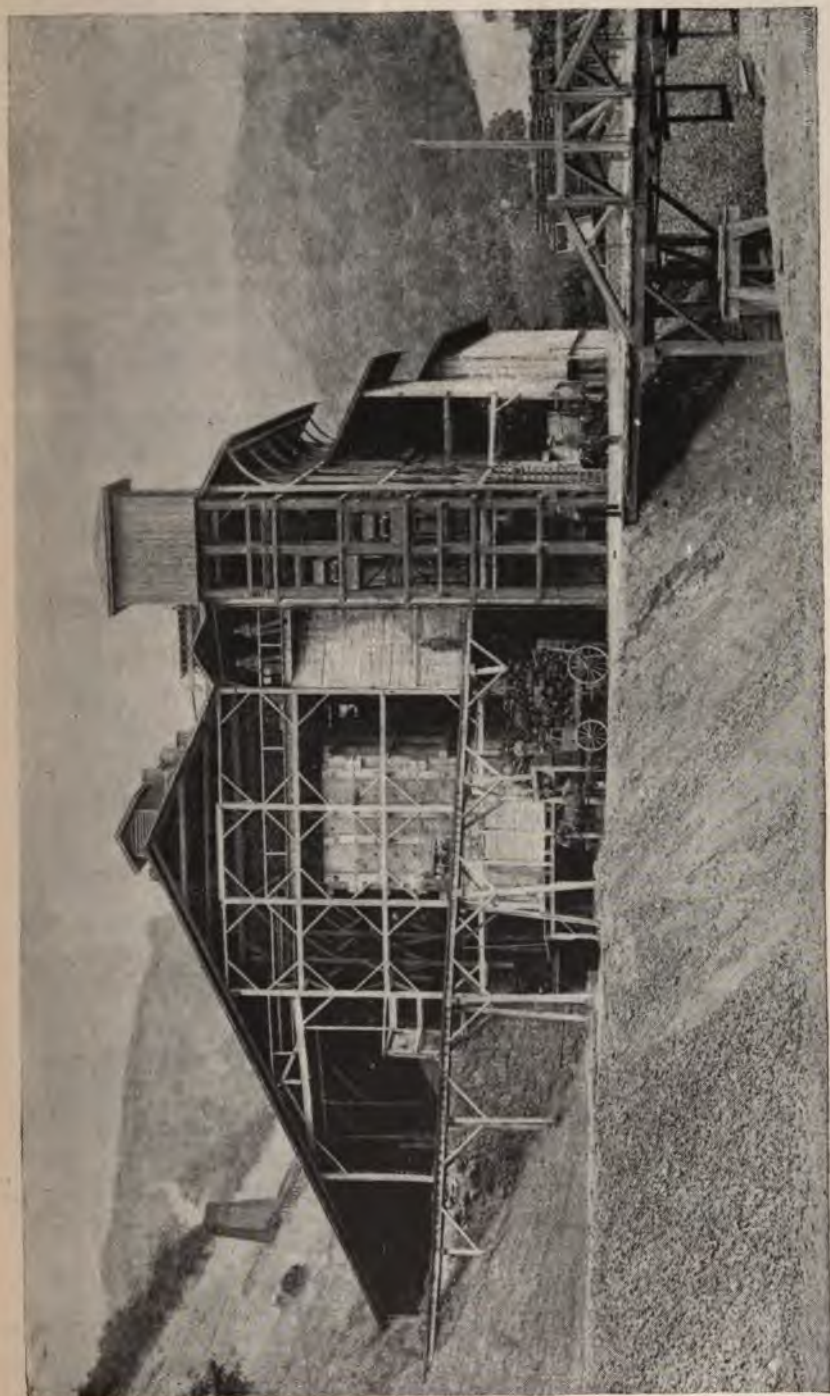
(14) Native mercury, collected from the labor just mentioned. After blasting it often runs out of the cavities in streams. (66453.)

(15) Cinnabar and veinstone. Interesting chiefly on account of the pyrite which it contains. This intermixture is quite common. Sulphides of several other metals are also found, but only occasionally, and in small quantities. (66454.)

(16) Serpentine, which forms the foot wall of the vein. It is usually in contact with and underlying the vein, but in absence of the vein it comes in sharp contact with the hanging wall. Sometimes there is a strong line of demarcation between the vein and foot wall; at others they shade off almost imperceptibly into each other. (66455.)



GENERAL VIEW OF REDUCTION WORKS, NEW ALMADEN QUICKSILVER MINE, CALIFORNIA.
(See explanation, page XVII.)



REDUCING FURNACE No. 1 FOR QUICKSILVER, NEW ALMADEN MINES, CALIFORNIA.
(See explanation, page XVII.)



The model of the mine consists of 26 plates of glass set at distances representing 50 feet apart. Upon these are drawn the outline of the surface ground, with the buildings; the shafts, tunnels, and working spaces underground; and the ore bodies. By looking through the plates as they stand one can see represented the whole mine and its surroundings. It is constructed on a scale of 100 feet to the inch. (66456.)

The operation of the furnace is illustrated by—

- (1) Average sample of lump ore "Granza." (51621.)
- (2) Roasted Granza. (51622.)
- (3) Coarse ore or "Granzita." (51657.)
- (4) Coarse Tierras or "Granzita" roasted. (51625.)
- (5) Fine ore or "Tierras." (51623.)
- (6) Fine ore or "Tierras" roasted. (51624.)
- (7) Wood, used for fuel. (51626.)
- (8) Soot, from condensers. (51627.)
- (9) Acid water, from condensers. (51590.)
- (10) Miniature quicksilver flask. (51628.)
- (11) Pure quicksilver. (51589.)

ALUMINIUM.

ALUMINIUM MINERALS.

CORUNDUM.

Composition: Al_2O_3 . Sesquioxide of aluminium containing aluminium 53.4 per cent. and oxygen 46.6 per cent., generally containing a small amount of iron.

It crystallizes in the rhombohedral system, prismatic and pyramidal planes predominating. Large rough crystals are quite common. It also occurs massive and granular. Its hardness is 9, being next to the diamond. It varies in specific gravity from 3.90 to 4.16. It occurs in a large variety of colors, especially reds and blues, and white. It is transparent to translucent, and has a vitreous luster. Clear, transparent, red corundum forms the gem, ruby, while the blue forms sapphire.

The most important use of corundum is for grinding purposes, but small amounts have been smelted direct for aluminium. Three illustrations of corundum are shown here, and a full suite will be found with the grinding and polishing materials.

- (1) Rough crystal. Shimerville, Lehigh County, Pennsylvania. (66573.)
- (2) Decomposed rock, containing corundum. Shimerville, Lehigh County, Pennsylvania. (66574.)
- (3) Lump corundum. Alabama. (66575.)

BAUXITE.

Composition: $(\text{AlFe})_2\text{O}_3 \cdot 2\text{H}_2\text{O}$. Hydrated sesquioxide of aluminium, containing variable amounts of iron, silica and titanitic acid are also generally present. Its general occurrence is oolitic and clay like.

Bauxite is an abundant source of aluminium. Three characteristic samples from a deposit in Floyd County, Georgia, are shown :

- (1) Oolitic and porous, slightly stained by iron. (66576.)
- (2) Oolitic, stained by iron. (66577.)
- (3) Oolitic, hard and compact, very red from iron. (66578.)

An analysis by Prof. J. W. Langley shows it to contain :

	Per cent.
Silica (SiO_2).....	16.01
Titanic acid (TiO_2)	6.33
Water (H_2O).....	25.27
Sesquioxide of iron (Fe_2O_3).....	0.70
Alumina (Al_2O_3)	*51.69
	<hr/>
	100.00
Aluminium (Al)	27.49

CRYOLITE.

Composition : $\text{Al}_2\text{Na}_6\text{F}_{12}$. Fluoride of aluminium and sodium, containing aluminium 13 percent., sodium 32.8 per cent., and fluorine 54.2 per cent.

It crystallizes in the triclinic system in tabular crystals, generally occurs massive, showing cleavage. Its hardness is 2.5, and specific gravity varies from 2.9 to 3.077. It is generally white, although it may be tinged or black, and translucent.

Cryolite is an abundant source of aluminium since it used for the manufacture of carbonate of soda, and alumina is obtained as a by-product. It is found in large amounts only in Greenland, and is illustrated by a single characteristic specimen.

- (1) Massive, containing siderite, galena, and chalcophyrite. (17571.)

CLAY.

Under this head are included several hydrated silicates of aluminium of very varying composition, which will be more fully described further on.

Aluminium is a constituent of many other minerals, but they are not used for the manufacture of the metal.

EXTRACTION OF ALUMINIUM.

Although aluminium is a constituent of so many common minerals, its extraction is very difficult and expensive, owing to the tenacity with which it holds on to oxygen. The first step is the preparation of the anhydrous sesquioxide, alumina (Al_2O_3), in as pure a condition as possible. For this purpose the aluminium minerals are treated chemically by long and complicated processes. Having a pure alumina, it is first converted into anhydrous chloride, and the metal is then reduced from this by means of metallic sodium. Formerly this was the only method

* By difference.

of making pure aluminium, but recently several methods of producing the metal direct from the oxide by electric smelting have been proposed, and give promise of being successful.

Alloys of copper and aluminium are also smelted, sometimes from corundum, by reducing the aluminium in presence of metallic copper, with which it immediately alloys.

The collection donated by Col. William Frishmuth contains twelve specimens, and shows several steps in the process, together with a full series of products.

- (1) Corundum, consisting of oxide of aluminium. North Carolina. (50596.)
- (2) Sulphate of aluminium and sodium, prepared from corundum. (50597.)
- (3) Alumina, precipitated from the sulphate of aluminium and sodium. (50598.)
- (4) Double chloride of aluminium and sodium, made from the precipitated anhydrous alumina. (50599.)
- (5) Metallic aluminium, in globules, first smelting. (50600.)
- (6) Ingot and sheet. (50601.)
- (7) Wire. (50602.)
- (8) Foil. (50603.)
- (9) Bronze powder. (50604.)
- (10) Soldered. (50605.)
- (11) Alloyed with copper, known as aluminium gold. (50606.)
- (12) Sheet brass and copper wire; electroplated with aluminium. (50607.)
- (1) Ingot, smelted from alumina dissolved in a heated bath of fluorides and subjected to the action of a powerful electric current, by the Hall process. (51629.)
- (2) Sheet metal, rolled from ingot No. 51,629, 0.0005 of an inch thick. (51630.)
- (3) Alloy of aluminium and copper, containing 42 per cent. aluminium, smelted from alumina by a powerful electric current in the presence of copper, by the Heroult process. (51631.)

CHROMIUM.

CHROMIUM MINERAL AND ORE.

CHROMITE.

Composition: FeOCr_2O_3 . Protoxide of iron and sesquioxide of chromium, containing iron protoxide 32 per cent. and chromium sesquioxide 68 per cent. Magnesia generally replaces some of the protoxide of iron and alumina the sesquioxide of chromium. Besides iron is frequently present as sesquioxide and chromium as protoxide.

It crystallizes in the isometric system, showing octahedrons, but generally occurs fine granular or massive. Its hardness is 5.5 and specific gravity 4.321. It is black and has a submetallic luster. Sometimes it is magnetic.

Chromite generally occurs in or with serpentine. It is used mainly for the manufacture of chromates for painting, dyeing, and the like. Small amounts are used to produce chromium steel. Chromite occurs only sparingly in nature, and the collection illustrates the principal United States localities.

- (1) Very fine granular, with streaks of decomposition products. Wood's Mine, Lancaster County, Pennsylvania. (11681.)
- (2) Crystalline sand, with fine sharp crystals. Lancaster County, Pennsylvania. (5179.)

- (3) Crystalline sand, with rough, coarse, crystals. Oxford, Chester County, Pennsylvania. (65353.)
- (4) Crystalline sand, with considerable impurity. Carter's Mine, Madison County North Carolina. (56310.)
- (5) Coarse granular. Webster, Jackson County, North Carolina. (65428.)
- (6) Coarsely crystalline and foliated. Placer County, California. (65351.)
- (7) Granular. Del Norte County, California. (65349.)
- (8) Crystalline and impure. San Luis Obispo County, California. (66350.)

BISMUTH.

BISMUTH ORES.

- (1) Oxidized ore, contains 55 to 60 per cent. of metallic bismuth. Northern Sp Mine, Juab County, Utah. (55341.)
- (2) Oxidized ore. Bismuth Mine, Granite District, Beaver County, Utah. (55341.)

ALLOYS.

PRECIOUS METAL ALLOYS.

In treating auriferous copper containing bismuth Mr. Richard Pearce discovered some beautiful crystals of an alloy of gold and bismuth, and in studying the matter has formed a very interesting series of crystalline alloys of the precious metals.

- (1) Ascicular crystals, brown-gray. Containing gold 69.94 per cent., silver 0.6 per cent., bismuth 29.43 per cent. = $\text{Au}_{12}\text{Bi}_5$. (55975.)
- (2) The same alloy, copper-red in color. (55976.)
- (3) The same alloy, oxidized below its melting point; greenish-yellow. (55977.)
- (4) Octahedral crystals, containing gold 69 per cent., silver 21 per cent.; yellow (55978.)
- (5) Crystalline alloy, containing gold 62.164 per cent., silver 35.486 per cent., copper and bismuth 2.350 per cent.; bright yellow. (55979.)
- (6) Crystalline alloy, containing gold 65.21 per cent., silver 33.19 per cent., copper 1.60 per cent.; very bright yellow. (55980.)
- (7) Crystalline alloy, containing gold 58.51 per cent., silver 39.16 per cent., copper 2.33 per cent. = Au_8Ag_6 ; pale yellow. (55981.)
- (8) Crystalline alloy, containing gold 94.15 per cent., silver 4.43 per cent.; reddish yellow. (55982.)
- (9) Octahedral crystals, containing gold 61.52 per cent., copper 38.48 per cent. = AuCu_2 ; reddish. (55983.)
- (10) Octahedral crystals, containing gold 93.49 per cent., copper 6.51 per cent.; reddish. (55984.)
- (11) Crystals, containing gold 60.16 per cent., silver 21.21 per cent., copper 18.63 per cent.; yellowish-gray. (55985.)
- (12) Crystals, liquated from melted bismuth, containing gold 59.06 per cent., silver 37.21 per cent., copper and bismuth 3.73 per cent.; yellow. (55986.)

BRASS.

Brass is an alloy of copper and zinc in varying proportions, to which at times other metals are added in small amounts to give certain characters to the alloy. It is applied to a large variety of uses familiar to

every one, and takes the place of copper in many cases where it answers just as well and costs considerably less.

In the manufacture of brass a certain amount of scrap brass is first melted in a crucible, in order to give a fluid bath on the bottom of the crucible, and into this is put the proper amount, depending upon the grade of brass desired, of copper, which is melted. The contents of the crucible must now be brought to just the right temperature; if it is too cold it is heated; if too hot, and this is generally the case, it is cooled or tempered by adding strips of brass. If it is too cold the zinc will not mix properly with the copper; if it is too hot the zinc will be volatilized and the contents of the crucible boil over.

Being at the right temperature the zinc is added. Since zinc oxidizes very easily it is customary to add an excess, about 5 per cent., for loss, but with care it is possible to reduce the loss to 1 per cent. Sometimes small amounts of other metals, especially lead, are added to give special qualities to the brass. When the zinc is thoroughly incorporated with the copper the melting is finished and the brass is ready to be cast. The form into which it is cast depends upon the use to which it is to be put.

Great care is required in casting to secure good results. The crucible is first skimmed and then poured. If poured too fast air will be entangled with the metal and the casting will be unsound from blow holes; if poured too slow dross will catch on the sides of the mold and make bad spots in the casting. The crucibles hold 100 to 130 pounds, and, since the work is very exhausting, the melters work only 6 to 8 hours a day, producing five to six heats. The average product of good brass is about 75 per cent. of the materials charged.

The manufacture and utilization of brass as practiced at the works of the Ansonia Brass and Copper Company, Ansonia, New Haven County, Connecticut, is illustrated by a full collection taken by Mr. Henry Cooper, 1884.

- (1) Copper, used in the manufacture of brass. (54393.)
- (2) Spelter or metallic zinc, used in the manufacture of brass. (54378.)
- (3) Pig lead, used in the manufacture of brass. (54394.)
- (4) Scrap brass, obtained from the ashes of the casting shop by washing. (54395.)
- (5) Oxide of zinc, obtained as a efflorescence in working up the refuse of the casting shop on letting the metal stand for a long time in the crucible in the furnace. (54396.)
- (6) Brass crucible, in use for fifty rounds of melting. (54399.)
- (7) Common or high brass, shows the brass as cast into a bar one and one-quarter inches thick, and the bar reduced to one-quarter inch thick by rolling. Composition, two parts copper to one part zinc. (54386.)
- (8) Brass, that can be worked hot or cold, showing the bar as cast, and the reduction of the same bar by rolling; the cast rod 2 inches square is broken down to seven-eighths of an inch round, hot, and finished cold. Composition, three parts copper to two parts zinc. (54376.)
- (9) Brass, that can be worked hot or cold; a test piece hammered out hot. Composition, three parts copper to two parts zinc. (51186.)
- (10) Clock brass, embossed. (54390.)

- (11) Clock brass, a movement put together. (54391.)
- (12) Spinning brass. (54377.)
- (13) Cartridge metal, showing different stages in the production of the cartridge, and tests to prove the quality of the metal. (54373.)
- (14) Tubing, composition, four parts copper to one part zinc. (54388.)
- (15) Rich gold metal, showing the bar as cast, and the reduction of the same bar by rolling. (54375.)
- (16) Rich gold spinning metal, spun to shape without annealing. (54387.)
- (17) Rich gold metal tubing. (54389.)
- (18) Brass solder, used for brazing richer brasses and copper. Composition, one part copper to one of zinc, No. 0. (54379.)
- (19) Brass solder, No. 1. (54380.)
- (20) Brass solder, No. 2. (54381.)
- (21) Brass solder, No. 3. (54382.)
- (22) Brass solder, No. 4. (54383.)
- (23) Brass solder, No. 5. (54381.)
- (24) Brass solder, No. 6. (54385.)
- (25) Brass rods, for wire-drawing; shows a bar cast one-half inch by one-quarter inch, reduced, first by rolling and then drawing down, to one-eighth inch diameter. (54392.)
- (26) Brass wire, fine. (54397.)
- (27) Brass wire, with a thread cut in it for making "cabled wire shoe-pegs." (51212.)
- (28) Dies, for wire-drawing. (54374.)

A series of alloys manufactured by Messrs. Merchant & Company, of Philadelphia, includes a full series of Babbitt metals, solders, and a few other commercial alloys.

Babbitt or anti-friction metals.

- | | |
|---|--|
| <ul style="list-style-type: none"> (1) Genuine or copper hardening. (54455.) (2) Genuine or copper hardening, showing fracture. (54449.) (3) Grade A. (54450.) (4) Grade A, showing fracture. (54444.) (5) Grade B. (54451.) | <ul style="list-style-type: none"> (6) Grade B, showing fracture. (54445.) (7) Grade C. (54452.) (8) Grade C, showing fracture. (54446.) (9) Grade D. (54453.) (10) Grade D, showing fracture. (54447.) (11) Grade E. (54454.) (12) Grade E, showing fracture. (54448.) |
|---|--|

Solder.

- (1) Composition, 40 parts tin, 60 parts lead. (54456.)
- (2) Composition, 80 parts tin, 100 parts lead. (54457.)
- (3) Composition, 90 parts tin, 100 parts lead. (54458.)
- (4) M. F. Composition, 106 parts tin, 100 parts lead. (54459.)
- (5) Half and half, composition 100 parts tin, 100 parts lead. (54461.)
- (6) Capping, composition, 100 parts tin, 100 parts lead. (54462.)
- (7) Triangular, composition, 80 parts tin, 100 parts lead. (54463.)
- (8) Plumbers extra wiping, composition, 105 parts tin, 200 parts lead. (54465.)
- (9) Plumbers extra wiping, composition 125 parts tin, 200 parts lead. (54466.)
- (1) Stereotype metal. (54472.)
- (2) Bolster metal. Used for filling cutlery handles, etc. (54473.)
- (3) Copper. Used in the manufacture of alloys. (54476.)
- (4) Tin. Used in the manufacture of alloys. (54460.)
- (5) Antimony. Used in the manufacture of alloys. (54478.)
- (6) Lead. Used in the manufacture of alloys. (54464.)
- (7) Zinc. Used in the manufacture of alloys. (54477.)

COLLECTIONS IN ECONOMIC GEOLOGY AND METALLURGY. 199

A series of alloys manufactured by Mr. Paul S. Reeves, Philadelphia, Pennsylvania, includes a full series of Babbitt metals, some bronzes and brass.

Babbitt or antifriction metals.

- | | |
|--|-----------------------|
| (1) Grade XXX, genuine. (55640.) | (6) Grade C. (55645.) |
| (2) Grade XX, copper hardening. (55641.) | (7) Grade D. (55646.) |
| (3) Grade X, copper hardening. (55642.) | (8) Grade E. (55647.) |
| (4) Grade A. (55643.) | (9) Grade F. (55648.) |
| (5) Grade B. (55644.) | |

Bronzes.

- (1) Gun-metal bronze, composition nine parts copper, one part tin. (55649.)
- (2) Journal-metal bronze, composition seven parts copper, one part tin. (55650.)
- (3) Roman bronze, for journal bearings. (55652.)
- (4) Roman bronze, for pump rods, cog wheels, etc. (55653.)

Brass.

- (1) Composition three parts copper, one part zinc. (55651.)

A special alloy made particularly for bearings and resistance to chemical fluids, containing copper, tin, and lead, and known as Ajax metal, is illustrated by two specimens, 50920 and 50921.

An alloy of tin and phosphorus for preparing phosphor bronze; known as Scandia phosphor-tin, is illustrated by 44300.

TYPE METAL.

The manufacture of type and type metal is fully illustrated by a collection contributed by Messrs. MacKellar, Smiths & Jordan, of Philadelphia, Pennsylvania; including the metals used, the different grades of type metals and the steps in the casting process.

- (1) Lead, for making type-metal alloy. (51214.)
- (2) Antimony, for making type-metal alloy. (51215.)
- (3) Tin, for making type-metal alloy. (51216.)
- (4) Copper, for making the matrix for casting the letter of the type. (51217.)
- (5) Script type metal. (51218.)
- (6) Hard type metal. (51219.)
- (7) Soft type metal. (51220.)
- (8) Electrotype metal. 51221.)
- (9) Die, for forming the letter in the matrix. (51222.)
- (10) Matrix, with the letter punched in it. (51223.)
- (11) Matrix, justified, ready to be used to cast the letter of the type. (51224.)
- (12) Type, as cast, two specimens. (51225.)
- (13) Finished type, a series of m in seventeen sizes. (51226.)
- (14) Defective and refuse type. (51227.)
- (15) Ringtail mold and ladle, as used in casting type by hand over 100 years ago. (51228.)
- (16) Improved lever mold, for casting by hand, introduced 1811. (51229.)
- (17) Machine mold, being the casting part of the intricate machine used at present in casting type. An American invention introduced in 1843, and since greatly improved. (51230.)

TIN PLATE.

Welsh tin plates of many grades are illustrated by a full series, presented by Messrs. Merchant & Co., Philadelphia, Pennsylvania.

- (1) Plate, prepared for coating. 1 C., 20 by 28 inches. (54492.)
- (2) Bright steel, used for the finest ware work, where it is not necessary to retin, it takes a fine polish; the body of the plate is of high grade, open hearth steel, and the coating of tin the thickest possible. Highest grade. Spencer, 1 C., 20 by 28 inches. (54479.)
- (3) Bright steel, used for the finest tinware work. Very high grade. Spencer 1, XXXX, 14 by 20 inches. (54481.)
- (4) Steel, with only a fair coating; used for tinware of a cheaper grade. Common quality. Raven, 1 C., 14 by 20 inches. (54485.)
- (5) Bright steel, a good quality of steel plate, with the thinnest coating of tin possible. Hexham, IX, 10 by 14 inches. (54486.)
- (6) Bright charcoal, made in all sizes and weights. High grade. Daffen, 1 C., 14 by 20 inches. (54480.)
- (7) Bright charcoal, a special size and thickness for certain kinds of heavy tinware. High grade. Killey, D., XXXX, 12½ by 17 inches. (54482.)
- (8) Bright charcoal, used for tinware. Good quality. E. C. C., IX, 10 by 14 inches. (54483.)
- (9) Bright charcoal, used for tinware of the commonest kinds. Common grade. Vole, XX, 12 by 12 inches. (54484.)
- (10) Bright coke, superior to many charcoal plates; used largely for salmon packing. Highest grade coke plate. Old Caster, 1 C., 12 by 24 inches. (54487.)
- (11) Bright coke, with the thinnest coating of tin possible; used largely for tinning and canning. Stick, 1 C., 14 by 20 inches. (54488.)
- (12) Steel terne or leaded, for roofing purposes; a box of 1 C., 20 by 28 inches, contains 36 pounds of tin and lead coating on a high grade, open hearth steel. It will stand very severe tests and requires no painting. Highest grade of roofing plate. Gilbertson's Old Method, 1 C., 20 by 28 inches. (54493.)
- (13) Steel terne or leaded, for roofing purposes. The body of this plate is of high grade, open hearth steel; it is considered one of the best plates for roofing, and stands very severe tests. High grade plate. Camaret, 1 C., 20 by 28 inches. (54495.)
- (14) Steel terne or leaded, for roofing purposes; showing various tests of the quality of the metal. Camaret, IX, 20 by 28 inches. (54496.)
- (15) Terne or leaded, for roofing purposes; heavily coated plate, formerly used extensively. M. F., 1 C., 20 by 28 inches. (54494.)
- (16) Terne or leaded, for roofing purposes. A standard brand for roofing. Gilbertson's (ordinary), 1 C., 20 by 28 inches. (54498.)
- (17) Charcoal terne or leaded, for roofing purposes. A standard brand for roofing, Melyn, 1 C., 14 by 20 inches. (54497.)
- (18) Terne or leaded, for roofing purposes. Good quality for roofing. Alyn, 1 C., 20 by 28 inches. (54499.)
- (19) Waster, bright charcoal, a defective sheet, the defects are blisters, holes, untinned spots, crooked sheets, etc. (54489.)
- (20) Thin, used extensively for tin boxes for mailing purposes. Taggers tin, 38 gauge, 10 by 14 inches. (54491.)
- (21) Thin iron plate, used extensively for boxes for mailing purposes. Taggers iron, 38 gauge, 10 by 14 inches. (54490.)

SULPHUR.

SULPHUR MINERALS.

SULPHUR.

Composition: S. Pure sulphur, frequently containing clay and carbonaceous matters.

It crystallizes in the orthorhombic system, showing especially a large variety of octahedral planes, crystals often complex and frequently twinned. It also occurs massive and in layers. It varies in hardness from 1.5 to 2.5 and the specific gravity is 2.072. It has a characteristic yellow color, but is sometimes reddish or greenish. It is transparent to translucent, and is sectile.

It is found in all volcanic regions, but especially on the Island of Sicily. Large deposits of it are known in Utah and Nevada. A single specimen is shown:

(1) Crystals on massive. Rabbit Hole Mine, Humboldt County, Nevada. (15455.)

The sulphide of iron, pyrite, and the sulphide of zinc, blende, the sulphur of which is sometimes utilized for the manufacture of sulphuric acid, have been described under iron and zinc minerals.

SULPHUR ORES.

Sulphur is found in nature, free, combined directly with various metals, and in oxidized compounds, of these the latter can not be used as a source of sulphur. Of the sulphides, only the bisulphide of iron, pyrite, and the sulphide of zinc, blende, have been utilized for their sulphur, and the latter only in connection with roasting the blende to remove the sulphur previous to smelting for zinc. Practically the only sources of sulphur are free sulphur and iron pyrite.

Free sulphur is found in all volcanic regions, but a very large portion of the world's supply is drawn from the Island of Sicily. It is found in large amounts in our Western country, but too far from transportation to be utilized. Iron pyrite is a very common mineral, but large deposits free enough from arsenic, to be used, are not common. Two or three mines, however, in this country produce large amounts of pyrite which are used for acid-making. When, as is quite frequent, pyrite contains a small amount of copper, the sulphur is sometimes utilized, and then the copper is extracted.

Almost the sole use of sulphur is for the manufacture of sulphuric acid. For this purpose the sulphur is burned to sulphurous acid (SO_2) on a grate, and then conducted with a slight excess of air into large lead chambers and mixed with steam and nitrous fumes, where the sulphurous acid (SO_2) is oxidized to sulphuric anhydride (SO_3)

and immediately takes on water and forms sulphuric acid (H_2SO_4). This chamber acid contains a large excess of water which must be evaporated to produce the strong acid or oil of vitriol. The process is practically the same whether sulphur or pyrite is used, except that in the latter case there is a large residue of oxide of iron left in the furnace after the combustion of the sulphur. Five characteristic specimens of pyrite are shown :

(1) Iron pyrite, containing, chalcopyrite, blende, and quartz. Coarse ore. Charlemont Mine, Franklin County, Massachusetts. (54144.)

(2) Iron pyrite, fine ore. Charlemont Mine, Franklin County, Massachusetts. (54145.)

(3) Iron pyrite, containing about 50 per cent. of sulphur. Granular ore. Arminius Sulphur and Copper Mine, Tolarsville, Louisa County, Virginia. (54239.)

(4) Iron pyrite, containing about 50 per cent. of sulphur. Lump ore. Arminius Sulphur and Copper Mine, Tolarsville, Louisa County, Virginia. (54242.)

(5) Iron pyrite with chalcopyrite, contains about 50 per cent. of sulphur. Lump ore. Arminius Sulphur and Copper Mine, Tolarsville, Louisa County, Virginia. (54241.)

The Arminius ores show on analysis :

	<i>Per cent.</i>	<i>Per cent.</i>
Sulphur (S).....	49.27	51.649
Iron (Fe).....	43.62	46.87
Copper (Cu).....	1.50	0.200
Zinc (Zn).....	0.038	
Lime (CaO).....	0.982	
Magnesia (MgO).....	0.338	
Arsenic (As).....	None.	None.
Silica (SiO ₂).....	4.23	1.278
Oxygen (O).....	0.018	
	100.00	99.997

THE MANUFACTURE OF SULPHURIC ACID FROM IRON PYRITE.

This process is illustrated by a collection from the Merrimac Chemical Works, Boston, Massachusetts.

Ore.

(1) Iron pyrite, containing a little quartz and calcite. Lump ore. Davis Mine, Charlemont, Franklin County, Massachusetts. (55457.)

(2) Iron pyrite, granular ore. Davis Mine, Charlemont, Franklin County, Massachusetts. (55458.)

(3) Roasted, the residue remaining after the sulphur has been burned off from the Davis ore, contains about one and one-quarter per cent. of copper. (55459.)

Products.

(1) Chamber acid, dilute sulphuric acid made from Davis ores. (55460.)

(2) Oil of vitriol, or concentrated chamber acid, made partly from the Davis ore and partly from brimstone. (55461.)

GRINDING AND POLISHING MATERIALS.

Under this head are included the naturally occurring materials which are used for cutting, abrading, grinding, and polishing in all its forms, such as grinding to remove superfluous material, to get a proper form or to give an edge, and polishing to give a suitable finish. For this purpose it is essential that the material shall be hard, and have a sharp cutting edge when broken into small pieces. This cutting edge determines the value of the material. These conditions being mainly physical a number of otherwise widely different minerals are used, and generally only certain varieties of a mineral. Thus, while quartz in the form of compact crystals, which break with a sharp edge, is a very good material, yet quartz in the form of a fine sand of rounded particles has almost no value.

The principal minerals used for this purpose are corundum and its impure form emery, several varieties of quartz and garnet, while other minerals are occasionally used. Of these corundum is by far the best, both on account of its hardness and sharp cutting edge. Some varieties of glassy quartz have such sharp edges when broken that they are very effective. Besides distinct minerals, several varieties of rocks are used, such as pumice stone, which is a volcanic feldspathic rock, and rotten stone, which is a very much decomposed rock.

CORUNDUM.

- (1) Rough crystals, with a little damourite. Cobb County, Georgia. (56340.)
- (2) Massive, with damourite. Lucas Mine, Rabun County, Georgia. (56356.)
- (3) Coarse sand. Carter's Mine, Madison County, North Carolina. (56311.)

The Georgia lump corundum and the commercial sizes ground from it are represented by twelve specimens from the Union Stone Company, of Boston, Massachusetts.

- | | |
|-------------------------------|---------------------------------|
| (1) Lump ore. (55886.) | (7) Ground, size 54. (55871.) |
| (2) Ground, size 18. (55876.) | (8) Ground, size 60. (55870.) |
| (3) Ground, size 20. (56875.) | (9) Ground, size 70. (55869.) |
| (4) Ground, size 24. (55874.) | (10) Ground, size 80. (55868.) |
| (5) Ground, size 30. (55873.) | (11) Ground, size 100. (55867.) |
| (6) Ground, size 40. (55872.) | (12) Ground, size 120. (55866.) |

EMERY.

Emery is an impure and softer form of corundum, and is of inferior quality for grinding.

Ore.

- (1) Corundum, magnetite, margarite and chlorite, rough crystals. Sackett Mine, Chester, Hampden County, Massachusetts. Two specimens. (4676.)
- (2) Ground, four grades; separated from the Chester ores. (18186) An average

sample of these four sizes, analyzed by Mr. J. A. Allen in the laboratory of the department, gave:

	Per cent.
Water (H_2O).....	1.35
Silica (SiO_2)	5.54
Alumina (Al_2O_3).....	56.15
Titantic acid (TiO_2).....	4.75
Sesquioxide of iron (Fe_2O_3)	19.82
Protoxide of iron (FeO)	9.17
Oxide of manganese (MnO).....	0.33
Lime (CaO).....	0.14
Magnesia (MgO)	2.17
	<hr/> 99.42

Turkey emery and the commercial sizes ground from it, are represented by twenty-three specimens from the Union Stone Company, Boston, Massachusetts.

(1) Lump, two specimens. (55885.)	(13) Ground, size 54. (55854.)
(2) Ground, size 10. (55865.)	(14) Ground, size 60. (55853.)
(3) Ground, size 12. (55864.)	(15) Ground, size 70. (55852.)
(4) Ground, size 14. (55863.)	(16) Ground, size 80. (55851.)
(5) Ground, size 16. (55862.)	(17) Ground, size 90. (55850.)
(6) Ground, size 18. (55861.)	(18) Ground, size 100. (55849.)
(7) Ground, size 20. (55860.)	(19) Ground, size 120. (55846.)
(8) Ground, size 24. (55859.)	(20) Ground, size F. (55847.)
(9) Ground, size 30. (55858.)	(21) Ground, size 2F. (55846.)
(10) Ground, size 36. (55857.)	(22) Ground, size 3F. (55845.)
(11) Ground, size 40. (55856.)	(23) Ground, size 4F. (55844.)
(12) Ground, size 46. (55855.)	

QUARTZ.

Massive quartz from North Carolina and the commercial sizes ground from it, are represented by nine specimens from the Union Stone Company, Boston, Massachusetts.

(1) Lump. (55887.)	(6) Ground, size $1\frac{1}{2}$. (55879.)
(2) Ground, size 4. (55883.)	(7) Ground, size 1. (55878.)
(3) Ground, size 3. (55882.)	(8) Ground, size $\frac{1}{2}$. (55877.)
(4) Ground, size $2\frac{1}{2}$. (55881.)	(9) Ground, size 0. (55884.)
(5) Ground, size 2. (55880.)	

TRIPOLI.

Tripoli consists of the siliceous shells of diatoms, and is therefore classed with quartz. It often forms thick deposits of sand which have simply to be washed to prepare it for a polishing powder. Large amounts of it are used for this purpose.

(1) Crude, from the mines of the St. Louis Tripoli Company, Missouri.	(2) Prepared. (55029.)
Two specimens. (55028.)	(3) Prepared. (51231.)
	(4) Prepared. (51232.)

A series of pumice stones and related products from the works of Messrs. R. J. Waddell & Co., New York, shows :

- (1) Pumice stone, lump. (54151.)
- (2) Pumice stone, flour, ground and bolted. (54154.)
- (3) Pumice stone, No. 1, ground and bolted. (54155.)
- (4) Pumice stone, No. 0, ground and bolted. (54156.)
- (5) Rotten stone, lump. (54150.)
- (6) Rotten stone, ground and bolted. (54153.)
- (7) Putty powder, first quality. (54149.)
- (8) Scotch hone, rough. (54146.)
- (9) Scotch hone, trimmed. (54147.)
- (10) Scotch hone, slip. (54148.)

Two specimens of garnet are shown :

- (1) Rough crystal. Burke County, North Carolina. (56322.)
- (2) Crushed. Burke County, North Carolina. (66583.)

MANUFACTURE OF SANDPAPER.

The collection illustrating the process of manufacturing sandpaper was presented by Messrs. Baeder, Adamson & Co., Philadelphia, Pennsylvania, and shows all the materials for making the paper, a full series of the lump and ground abrading materials, and a series of the sand and emery paper produced.

- (1) Manilla rope, used for manufacturing the paper. (55239.)
- (2) Paper pulp, manilla rope beaten into pulp, ready to be made into paper (55240.)
- (3) Manilla paper, made from rope, ready for the flint or emery. (55241.)
- (4) Glue stock, pieces of hide from which glue is made. (55237.)
- (5) Glue, made from hide; used for fastening the flint and emery to the paper. (55238.)

Flint rock or quartz.

- (1) To be ground and glued on to the paper; from Maine. (55243.)
- (2) From Pennsylvania. (55244.)

Ground, ready to be glued on to the paper :

- | | |
|-----------------------|-----------------------|
| (3) Size 00. (55253.) | (7) Size 1½. (55257.) |
| (4) Size 0. (55254.) | (8) Size 2. (55258.) |
| (5) Size ½. (55255.) | (9) Size 2½. (55259.) |
| (6) Size 1. (55256.) | (10) Size 3. (55260.) |

An average sample of these sizes, analyzed in the laboratory of the Department, by Mr. J. A. Allen, gave—

	Per cent.
Silica (SiO ₂)	99.00
Alumina (Al ₂ O ₃)	0.50
Sesquioxide of iron (Fe ₂ O ₃)	0.31
Lime (CaO).....	0.12
Magnesia (MgO)	0.16

(1) Flint paper, a roll as made and ready to be cut into sheets; the flint or quartz has been fastened on to the manilla paper by the glue. (55262.)

(2) Flint paper, a series of eight sheets, showing the different sizes of ground flint used. The sheets are one-fourth the regular size. (55264.)

Emery stone.

(1) To be ground and glued on to the paper; from Turkey. Two specimens. (55242.)

Ground, ready to be glued on to the paper:

(2) Size 00. (55245.)	(6) Size 1 $\frac{1}{4}$. (55249.)
(3) Size 0. (55246.)	(7) Size 2. (55250.)
(4) Size $\frac{1}{4}$. (55247.)	(8) Size 2 $\frac{1}{4}$. (55251.)
(5) Size 1. (55248.)	(9) Size 3. (55252.)

An average sample of these sizes, analyzed in the laboratory of the Department, by Mr. J. A. Allen, gave—

	Per cent.
Water (H ₂ O).....	3.60
Silica (SiO ₂)	10.69
Alumina (Al ₂ O ₃).....	58.98
Titanic acid (TiO ₂).....	2.79
Sesquioxide of iron (Fe ₂ O ₃)	10.57
Protoxide of iron (FeO)	11.89
Oxide of manganese (MnO).....	0.32
Lime (CaO).....	0.91
Magnesia (MgO).....	0.63
	<hr/> 100.38

(1) Emery paper, a roll as made and ready to be cut in to sheets; the emery has been fastened on to the manilla paper by the glue. (55261.)

(2) Emery paper, a series of eight sheets, showing the different sizes of ground emery used. The sheets are one-fourth the regular size. (55263.)

ASBESTOS.

Asbestos is a natural mineral fiber, incombustible and infusible at ordinary high temperatures. It finds wide application where resistance to high temperature is required. There are three minerals which occur in a fibrous form possessing the required characters; these are pyroxene, hornblende, and serpentine. Pyroxene and hornblende are essentially of the same chemical composition, being complex anhydrous bisilicates, containing alumina, iron, and magnesia. The fibrous varieties, however, generally contain little or no alumina, the average composition being, about, silica 55 per cent., protoxide of iron 12 per cent., and magnesia from 26 to 30 per cent.

It is very difficult, and in many cases impossible, to distinguish between pyroxene and hornblende in the fibrous state, since the difference between the two minerals is mainly in the habit of crystallization, and this is not shown by the fibers. It is only by association that they can be distinguished. In the collection no attempt has been made to separate the two minerals, since the specimens are entirely removed from all their associates. Hornblende is much more common in the fibrous form, and this name has been given to all the specimens except the serpentine.

Serpentine is a hydrated unisilicate of magnesia, containing silica 43.5

per cent., magnesia 43.5 per cent., and water 13 per cent. The fibrous variety is called chrysotile.

The name asbestos comes from the Greek for incombustible, since its resistance to heat is a marked characteristic of the material. It was also called amianthus, meaning undefiled, by the ancients, for the reason that cloth made from it could be cleaned by putting it into a moderate fire. The value of asbestos for practical uses depends upon its fiber, its infusibility, and its nonconducting power.

The highest grade hornblende asbestos comes from about 80 miles north of Milan in Italy. It occurs here in beds and pockets of light-gray and brown bundles of parallel fibers, firmly bound together, but single strands may be separated many yards in length, while it is very soft and greasy to the touch. This long, soft, silky fiber and its chemical purity give the Italian fiber its superiority.

Large amounts of chrysotile asbestos are mined in Canada in and about Thetford, Province of Quebec. It occurs as fibrous streaks or layers in compact serpentine. It seldom yields fibers over 7 inches long, but the shorter fibers are much more silky and therefore of better quality. For the manufacture of cloth this chrysotile asbestos is superior from the fact that the separated fibers cling together and form a mass like wool.

These two localities produce nearly all the first-class asbestos. The poorer grades of asbestos are quite abundant in many localities. They are poorer because the fiber is either short or hard or the material is impure, a very common impurity being oxides of iron, which give the material an undesirable color.

Asbestos, both hornblende and chrysotile, from a large number of localities is shown by a collection presented by the H. W. Johns Company, of New York.

Chrysotile.

- | | |
|---------------------|-----------------------------|
| (1) Vermont (5098.) | (2) New Hampshire. (50914.) |
|---------------------|-----------------------------|

Hornblende.

- | | |
|-------------------------------|---------------------------|
| (1) Massachusetts. (50909.) | (18) Georgia. (50873.) |
| (2) Massachusetts. (50910.) | (19) Alabama. (50903.) |
| (3) Connecticut. (50912.) | (20) Tennessee. (50905.) |
| (4) New York. (50867.) | (21) Iowa. (50915.) |
| (5) New York. (50868.) | (22) Wisconsin. (50906.) |
| (6) New York. (50869.) | (23) Utah. (50907.) |
| (7) New York. (50870.) | (24) Utah. (50908.) |
| (8) New York. (50871.) | (25) Dakota. (50916.) |
| (9) Pennsylvania. (50895.) | (26) Dakota. (50917.) |
| (10) Pennsylvania. (50896.) | (27) Nevada. (50885.) |
| (11) Pennsylvania. (50897.) | (28) Colorado. (50878.) |
| (12) Maryland. (50891.) | (29) Colorado. (50879.) |
| (13) Maryland. (50892.) | (30) Colorado. (50880.) |
| (14) Virginia. (50872.) | (31) California. (50899.) |
| (15) North Carolina. (50876.) | (32) Canada. (50886.) |
| (16) South Carolina. (50874.) | (33) Canada. (50887.) |
| (17) South Carolina. (50875.) | (34) Canada. (50890.) |

Chrysotile.

- | | | |
|----------------------|--|----------------------|
| (1) Canada. (50888.) | \| | (2) Canada. (50889.) |
|----------------------|--|----------------------|

Hornblende.

- | | | |
|---------------------------|--|------------------------------|
| (1) Manitoba. (50904.) | \| | (3) Newfoundland. (50919.) |
| (2) Nova Scotia. (50911.) | \| | (4) Victoria, B. C. (50902.) |

Mountain cork (Hornblende).

- | |
|-------------------------|
| (1) Venezuela. (50884.) |
|-------------------------|

Hornblende.

- | | | |
|-------------------------|--|--|
| (1) Australia. (50893.) | \| | (6) Spain. (50913.) |
| (2) Tasmania. (50918.) | \| | (7) Italy. (50894.) |
| (3) France. (50881.) | \| | (8) Smyrna. (50901.) |
| (4) France. (50882.) | \| | (9) China. (50900.) |
| (5) France. (50883.) | \| | (10) Transvaal, South Africa. (50877.) |

APPLICATION OF ASBESTOS.

In the account which Marco Polo gives of his travels he mentions an incombustible cloth which he saw in China. It was said to have been made from the hide of the salamander, but he found it to be asbestos, and he describes its manufacture. The Greeks made asbestos cloth, and it is supposed used it in the cremation of their dead to keep the ashes of the body separate. In modern days the most frequent use of asbestos is for the packing of steam joints, especially where high pressures are used. For this purpose it is made into paper or mill board, one thirty-second to one-half an inch thick, from which gaskets can be cut as desired, and into yarn or rope of various sizes and shapes to suit individual cases, and into special gaskets.

The very best quality is spun into thread and small-sized yarn, which can be woven into cloth for a variety of purposes, for filters, especially for corrosive fluids; for drop curtains for theaters; for clothes, especially gloves, for furnace men and firemen; for ladders and ropes for fire escapes; in fact, for any use exposed to heat. The poorer qualities are used as the basis of fireproof paint, for making nonconducting covering for steam boilers and pipes, for fireproof cement, and various other purposes.

The preparation and uses of asbestos are fully illustrated by a collection presented by the H. W. Johns Company, New York.

Chrysotile.

- | | | |
|-----------------------|--|----------------------|
| (1) Crude. (50859.) | \| | (3) Carded. (50861.) |
| (2) Fibered. (50860.) | \| | (4) Ground. (50862.) |

Hornblende.

- | | | |
|-----------------------|--|-----------------------|
| (1) Fibered. (50863.) | \| | (3) Fibered. (50865.) |
| (2) Fibered. (50864.) | \| | (4) Ground. (50866.) |

Products.

- | | |
|--|---|
| (1) Paper, four specimens. (50842.) | (15) Cord, soft, dyed several colors. (50836.) |
| (2) Mill board, or flat packing. Seven specimens, one-thirty-second to one-half inch thick. (50838.) | (16) Print roller cloth. (50853.) |
| (3) Piston packing, round. Seven specimens. (50841.) | (17) Cloth, for theater curtains, etc. (50851.) |
| (4) Wick packing. (50844.) | (18) Locomotive lagging, nonconducting. (50835.) |
| (5) Gaskets, four specimens. (50839.) | (19) Lining felt, nonconducting. (50837.) |
| (6) Asbestos and rubber steam packing, six specimens. (50840.) | (20) Lagging, air chamber, nonconducting. (50850.) |
| (7) Building felt. (50855.) | (21) Nonconducting cover for steam pipes, boilers, etc. (50854.) |
| (8) Roofing felt. (50852.) | (22) Retort cement. (50858.) |
| (9) Sheathing. (50843.) | (23) Plastic stove lining. (50857.) |
| (10) Thread. (50849.) | (24) Cement felting, for covering steam pipes, boilers, etc. (50856.) |
| (11) Thread. (50848.) | |
| (12) Yarn. (50847.) | |
| (13) Twine. (50846.) | |
| (14) Cord. (50845.) | |

P H O S P H A T E S.

PHOSPHATE MINERAL.

APATITE.

Compositions: $3\text{Ca}_3\text{P}_2\text{O}_8 + \text{CaCl}_2$ or $3\text{Ca}_3\text{P}_2\text{O}_8 + \text{CaF}_2$. Phosphate of lime, with chloride or fluoride of calcium, containing phosphoric acid 41 to 42.25 per cent., lime 53.8 to 55.55 per cent., and chlorine 6.82 per cent. or fluorine 3.77 per cent., chlorine and fluorine mutually replacing each other.

It crystallizes in the hexagonal system, showing especially prismatic and pyramidal planes, crystals often being highly modified. It also occurs fibrous, columnar, and granular massive. It varies in hardness from 4.5 to 5 and in specific gravity from 2.92 to 3.25. The common color is some shade of green, but many colors are found, and occasionally it is white. It is transparent to opaque and has a vitreous luster.

Apatite is the chief constituent of nearly all the native phosphates which occur in sufficient amounts to be mined for their phosphoric acid. A single specimen of crystallized apatite is shown here; others will be found with the phosphate ores.

- (1) Crystal. Templeton, Canada. (66572.)

PHOSPHATE ORES.

It is somewhat difficult to classify the native phosphates, since the several varieties graduate into each other and depend for the most part upon the physical condition and purity of the material. Mineral phosphates are generally quite pure, while rock phosphates are impure and run down to very low percentages of phosphate, as in the case of

marls, which generally find only local application. Under mineral phosphates we have the crystalline varieties or apatites and the foliated amorphous varieties or phosphorites. Under rock phosphates we have various nodular varieties, as the river phosphates of South Carolina, phosphatic limestones, guanos, and bone deposits.

Besides these phosphates of lime there are two, known as Redonda and Alta Veta phosphates, which are phosphates of iron and alumina.

The principal application of phosphates is for the manufacture of fertilizers, for which purpose they are sometimes simply ground very fine and applied directly to the land, but it is more frequent to treat them with sulphuric acid in order to render the phosphoric acid more easily available to vegetation. Besides the native phosphates, the highly phosphatic slag produced in the basic steel process is generally used for a fertilizer. It is simply ground very fine for use.

The native phosphates of lime used in the manufacture of fertilizers are illustrated by a series of mineral phosphates, apatites, and phosphorites; a series of the river phosphates of North and South Carolina; and three guanos. To these are added a sample of basic slag ground very fine.

APATITES.

Apatite occurs in a variety of rocks, but especially in crystalline limestone and granitic rocks, and in metallic veins. While it is a mineral of very common occurrence, yet large deposits of it have been found in only three countries, Canada, Norway, and Spain. Seven characteristic specimens of apatite are shown:

- (1) Rough crystals. North Burgess, Ontario, Canada. (30735.)
- (2) Massive, three characteristic specimens. North Burgess, Ontario, Canada. (30754.)
- (3) Massive. High Rock Mine, Buckingham, Province of Quebec, Canada; 100 feet deep. (64012.)
- (4) Massive. High Rock Mine, Buckingham, Province of Quebec, Canada; 120 feet deep. (64013.)
- (5) Massive. Canada (44278), of the following composition:

	Per cent.	Per cent.
Moisture at 212° (H ₂ O)	0.60	0.66
Water of combination (H ₂ O).....	0.59	0.13
Phosphoric acid* (P ₂ O ₅)	38.37	37.52
Lime (CaO).....	49.84	52.23
Oxide of iron and alumina ((FeAl ₂)O ₃)	1.14	7.37
Magnesia, etc., not determined (MgO).....	6.54	
Carbonic acid† (CO ₂)	0.64	
Insoluble matter.....	2.28	2.09
	α 100.00	b 100.00

* Equal to tribasic phosphate of lime, 83.76 and 81.91 per cent.

† Equal to carbonate of lime, 1.45 per cent.

α Analyst, G. H. Ogston.

b Analyst, Dr. Augustus Voelcker.

(6) Massive. Norway. (65122.)

(7) Massive. Zarza Mine, Spain (44276), of the following composition:

	Per cent.	Per cent.
Moisture at 212° (H ₂ O)	0.13	0.10
Water of combination (H ₂ O)	0.03	
Phosphoric acid * (P ₂ O ₅)	38.18	38.05
Lime (CaO)	50.57	
Oxide of iron and alumina ((FeAl ₂)O ₃)	3.61	0.30
Magnesia, etc., not determined (MgO)		
Carbonic acid (CO ₂)		
Insoluble matter	7.48	0.15
	a 100.00	(b)

a Analysts, Augustus Voelcker & Sons.

b Analyst, D. H. Gilbert.

* Equal to tribasic phosphate of lime, 83.35 and 83.07 per cent.

PHOSPHORITES.

Phosphorites differ mainly from apatites in their physical condition, and include the varieties of phosphate of lime which are not distinctly crystallized or crystalline. They are generally nodular and fibrous, but are sometimes earthy. The principal deposits are in Germany, France, and Spain. A single characteristic specimen of phosphorite is shown from Logrosan, Spain (44277), of the following composition:

	Per cent.
Moisture at 212° (H ₂ O)	0.35
Phosphoric acid * (P ₂ O ₅)	36.45
Lime (CaO)	49.40
Alumina, magnesia, etc., not determined	3.50
Insoluble matter	10.30
	100.00

Analysts, Teschemacker & Smith.

ROCK PHOSPHATES.

These differ from the mineral phosphates in being impure and occurring in relatively large masses. On this account they can be mined cheaper, and therefore do not need to be so pure and rich as the mineral phosphates.

RIVER PHOSPHATES.

River phosphates consist of nodules of varying size and shape, either free or cemented together, of a more or less impure phosphate of lime. The principal locality is in or near the rivers in the southern part of South Carolina, whence the name "River phosphates;" they are also found in North Carolina, Alabama, Florida, and England, France, Bel-

* Equal to tribasic phosphate of lime, 79.57 per cent.

gium, and Russia. River phosphates are by far the most important of the native phosphates.

The South Carolina phosphates vary in composition from 25 to 28 per cent. phosphoric acid, 35 to 42 per cent. lime, 2.5 to 5 per cent. carbonic acid, and 4 to 12 per cent. sand.

Ten specimens show the varying character of the river phosphates.

- (1) Ashley River, South Carolina. (34328.)
- (2) Middleton's Place, Ashley River, South Carolina. (34327.)
- (3) Stono River, South Carolina. (34326.)
- (4) Cohis Place, Cooper River, South Carolina. (34316.)
- (5) Bull River, South Carolina. (34321.)
- (6) Bull River, South Carolina. (34322.)
- (7) Bull River, South Carolina. (34323.)
- (8) Cast of a Venus shell Coosaw River, South Carolina. (34318.)
- (9) Vertebra. Coosaw River, South Carolina. (34317.)
- (10) Two characteristic specimens. New Hanover County, North Carolina. (44245.)

PHOSPHATIC LIMESTONE.

Phosphatic limestones are simply limestones containing more or less phosphate of lime. At present they are not utilized to any extent, and are mainly interesting as being the probable source of the richness of some soils. They are not illustrated in the collection.

GUANOS.

Guanos consist, essentially, of the excrement of birds. They are found mostly on small islands where birds are plentiful, especially on the islands of the Pacific and the West India Islands, although limited deposits are found on the large islands and the continents. The original deposits contain much soluble material, and sometimes this has been washed out by both sea and rain water, giving a leached guano.

The original or unleached guanos are found principally on the islands off the coasts of Peru and Bolivia, and are frequently known as Peruvian guano. They contain from 1 to 20 per cent. of nitrogen, 10 to 50 per cent. phosphate of lime, 1 to 6 per cent. potash, and 10 to 30 per cent. of water, forming a very valuable fertilizer. They are generally used without any chemical treatment, being simply ground. A single specimen is shown here:

- (1) From the top of Little Bird Rock, Gulf of St. Lawrence. July 9, 1887. (66580.)

Leached guanos are the insoluble portions of the original guano. They consist of sandy phosphate containing nodules, varying from loosely coherent to quite solid masses, and are also quite variable in composition. They are found on islands near the equator in the Pacific Ocean, and on many of the West India Islands, the most noted being the Navassa and Sombrero Islands.

Three specimens illustrate the leached guanos:

(1) Sombrero, British West India Islands (44275), of the following composition:

	<i>Per cent.</i>	<i>Per cent.</i>
Moisture, at 212° (H ₂ O)	2.76	3.55
Water of combination (H ₂ O)	2.72	1.85
Phosphoric acid* (P ₂ O ₅)	34.98	34.27
Lime (CaO)	49.28	48.04
Oxide of iron and alumina ((FeAl ₂)O ₃)	1.85	.....
Magnesia, etc., not determined (MgO)	1.61	11.39
Carbonic acid† (CO ₂)	5.70	.....
Insoluble matter	1.10	0.90
	<i>a</i> 100.00	<i>b</i> 100.00

a Analysts, G. H. Ogston.

b Analysts, Augustus Voelcker & Sons.

* Equal to tribasic phosphate of lime, 76.38 and 74.81 per cent.

† Equal to carbonate of lime, 12.95 per cent.

(2) Swan Island. (10680.)

(3) Swan Island. (10685.)

BONE DEPOSITS.

Bone deposits are generally found in caves, on the edges of shallow lakes, and on some northern islands, especially where the penguin congregates. They consist of the bones of animals and birds which have died there or been brought by carnivorous animals. The deposits are generally small.

A single specimen is shown here.

(1) Bones of the penguin mixed with moss. Funk Island off Newfoundland. July 23, 1887. (66581.)

C L A Y S .

Under this head are included several well-defined minerals, some doubtful and impure species, and various mixtures. They are applied to a large variety of widely different uses, so that it is impossible to give a general definition. Chemically they are all hydrated silicates of alumina, but they vary much in the relations between alumina, silica, and water, and are sometimes very impure. The most common impurity is siliceous sand, and clays imperceptively graduate into sands.

Nearly all clays contain the mineral kaolinite as an essential constituent, which, when pure, contains silica 46.3 per cent., alumina 39.8 per cent., water 13.9 per cent. Some of the purest clays approach this composition, but all contain small amounts of other materials, especially titanitic acid, iron, and potash. Besides kaolinite clays frequently contain quartz, especially as sand, titanitic acid minerals, feldspars, micas, pyrite, lignite, oxides, and carbonates of iron and other silicates. Occasionally many other minerals are found. A few clays do not contain kaolinite, but have the related mineral halloysite as a basis. Halloysite when pure contains silica 43.3 per cent., alumina 37.7 per cent., and water 19 per cent.

The following analyses taken from the report of the New Jersey Geological Survey upon clay deposits show the wide variation which occurs in the chemical composition of different characteristic clays.

	Silica, combined. (SiO_2)	Alumina. (Al_2O_3)	Water, combined. (H_2O)	Titanic Acid. (TiO_2)	Silica, quartz sand. (SiO_2)	Potash. (K_2O)	Soda. (Na_2O)	Lime. (CaO)	Magnesia. (MgO)	Sesquioxide of iron. (Fe_2O_3)	Water, Hygroscopic. (H_2O)	Total.
<i>Fire clays.</i>												
Woodbridge, N. J.	43.90	38.24	14.10	1.30	1.10	0.15	0.00	trace	0.11	0.96	0.70	100.56
Cheltenham, Mo.	38.10	31.53	11.30	1.50	12.70	0.40	.....	.....	trace	1.92	2.50	99.95
Utica, La Salle County, Ill.	38.25	26.45	9.80	1.15	18.40	1.10	.....	.....	0.30	2.10	2.10	99.65
Bonhamtown, N. J.	17.90	15.50	4.90	1.60	57.35	0.17	.....	.....	.....	1.20	1.30	99.92
<i>White clays.</i>												
Raritan River, N. J.	64.00	29.08	6.80	.....	.....	2.64	.....	.....	.....	1.12	3.76	.....
Old Bridge, N. J.	24.55	19.85	5.70	1.00	44.80	1.90	0.32	.....	.....	1.00	0.90	100.02
<i>Front brick clay.</i>												
Sayreville, N. J.	28.30	27.42	0.60	1.00	27.80	2.71	.....	.....	0.18	2.68	2.90	99.50

Physically clays vary from soft plastic or unctuous mud, as found in moist locations, to dry, hard, and rock-like deposits as often found below the Coal Measures.

The only general property belonging to all clays is, that with water they form an adhesive paste. Some clays show this in their natural condition or on being moistened with water, while others have to be ground in order to make a good paste. This property is called plasticity, and varies very much in different clays. On being heated so as to drive out the water of combination the plasticity is destroyed. Upon these two facts depends the value of clay for most purposes. Its plasticity allows the easy molding of the material into any desired shape, while subsequent heating or baking permanently sets or fixes the form.

According to their uses clay may be divided into pottery clay, refractory or fire clay, and brick and tile clay.

Under the head of pottery clays are generally included earthenware, including stoneware, ironstone, white, china, and porcelain clays. Pure white clays, free from oxide of iron, constitute the ironstone, china, white, and porcelain ware clays. In use other materials are generally mixed with them to secure the proper composition. Less pure clays, and those containing iron, constitute the earthenware clays. They may be of various colors, and when burned are some shade of red or brown. When sufficient iron is present to partially fuse during burning it becomes a stoneware clay.

Refractory or fire brick clays generally contain much quartz, and they must be able to stand a very high temperature without fusing. They

are used for the manufacture of gas and other retorts, glass pots, and fire brick of every description.

Under brick and tile clays are included a vast number of ordinary clays that are not good enough for other purposes. They are found widely distributed over the whole world, and are used for the manufacture of building brick of all kinds, tiles, pipe, terra cotta, and other articles of common use familiar to all.

The following table shows the wide range of application of clays :

Articles manufactured from clay in the United States.

I. Building materials :

1. Common building brick.
2. Front building brick (pressed brick, molded, intaglio, or ornamental brick.)
3. Hollow brick.
4. Glazed brick.
5. Roofing tile.
6. Flue linings.
7. Door knobs and hardware porcelain.
8. Terra cotta lumber.
9. Hollow tile, fireproofing, or castings.

II. Refractory materials

1. Fire brick.
2. Gas retorts.
3. Retorts for zinc works and for other metallurgical purposes.
4. Glass pots.
5. Stove and furnace linings.
6. Chemists and assayers utensils.

III. Pottery :

1. Stoneware.
2. Earthenware (yellow ware, Rockingham ware.)
3. Granite or ironstone ware.
4. White ware.
5. Porcelain (as part of mixture.)

IV. Ornamental ware :

1. Encaustic tile, for walls and floors.
2. Ornamental pottery.
3. Ornamental terra cotta.

V. Miscellaneous :

1. Sewer pipe.
2. Drain pipe or drain tile.
3. Flower pots.
4. Garden border edging.
5. Telegraph insulators.
6. Well tubing.
7. Receivers for acids.
8. Water filters and coolers.
9. Lamp stands.

Besides the above, certain qualities of clay are used for special purposes. In paper making it is used to give a finish to wall papers, and also to give weight and body to writing and other papers. In the manufacture of alum it is used as the source of alumina. In the manufacture of Portland cement clays are sometimes used.

The collection shows, first a series of the typical clays of New Jersey, and to these are added some characteristic clays from other localities.

NEW JERSEY CLAYS.

Pottery clays.

- (1) Kaolin. Edgar Pit, Woodbridge, Middlesex County. (11647.)
- (2) Kaolin. Weideners' Pit, Perth Amboy, Middlesex County. (11649.)
- (3) Kaolin. Woodbridge, Middlesex County. (33081.)
- (4) Ware clay. Cutter's Pit, Woodbridge, Middlesex County. (11635.)
- (5) Ware clay. Longbridge & Power's Pit, Woodbridge, Middlesex County. (11644.)
- (6) Ware clay. Woodbridge, Middlesex County. (33087.)
- (7) Earthenware clay. Roberts Pit, Woodbridge, Middlesex County. (11646.)
- (8) Earthenware clay. Rose & Sons' Pit, Woodbridge, Middlesex County. (11656.)
- (9) Earthenware clay. Woodbridge, Middlesex County. (33082.)

Refractory clays.

- (1) Fire clay. Weber's pit, Woodbridge, Middlesex County. (11629.)
- (2) Retort clay. Berry's pit, Woodbridge, Middlesex County. (11626.)
- (3) Fire sand. Valentine's pit, Woodbridge, Middlesex County. (11639.)
- (4) Sandy clay, extra. Longbridge & Power's Pit, Woodbridge, Middlesex County. (11640.)
- (5) Fire-brick clay, No. 1, burnt. Woodbridge, Middlesex County. (33086.)
- (6) Fire-brick clay, No. 2. Woodbridge, Middlesex County. (33080.)
- (7) Stove-lining clay. Woodbridge, Middlesex County. (33078.)
- (8) Molding sand. Woodbridge, Middlesex County. (33089.)
- (9) Sand. Woodbridge, Middlesex County. (33090.)
- (10) Fire clay. A. Weber's farm, Raritan River. (31339.)
- (11) Top white clay. A. Weber's farm, Raritan River. (31331.)
- (12) Top white clay. A. Weber's farm, Raritan River. (31332.)

Six manufactured articles from the Weber clays are also shown :

- | | |
|----------------------------|--|
| (1) Muffle. (31316.) | (4) Fire brick, No. 1, extra. (31323.) |
| (2) Muffle. (31317.) | (5) Fire brick, No. 1, small. (31325.) |
| (3) Checker work. (31320.) | (6) Fire brick, grate. (31327.) |

Brick and tile clays.

- (1) Pipe clay, black. Woodbridge, Middlesex County. (11645.)
- (2) Drain-pipe clay. Woodbridge, Middlesex County. (33077.)
- (3) Drain-pipe clay. Woodbridge, Middlesex County. (20285.)

Special clays.

- (1) Paper clay, white. South Amboy, Middlesex County. (11651.)
- (2) Paper clay, yellow. South Amboy, Middlesex County. (11654.)
- (3) Paper clay. Woodbridge, Middlesex County. (33084.)
- (4) Alum clay. South Amboy, Middlesex County. (11655.)
- (5) Kaolin, lump. East Fishkill, Dutchess County, New York. (34136.)
- (6) Kaolin, washed. East Fishkill, Dutchess County, New York. (34135.)
- (7) Kaolin. West Chester, Chester County, Pennsylvania. (66579.)
- (8) Kaolin. Bryson's Mica Mines, Macon County, Georgia. (29713.)
- (9) Kaolin. Augusta, Lincoln County, Georgia. (29712.)
- (10) Kaolin. Lawrence County, Indiana. (34441.)

- (11) Pottery clay. West Chester, Chester County, Pennsylvania. (66579.)
- (12) Pottery clay. Delaware. (29710.)
- (13) Pottery clay. Columbia, Richland County, South Carolina. (29728.)
- (14) Pottery clay. Columbia, Richland County, South Carolina. (33976.)
- (15) Pottery clay. Augusta, Lincoln County, Georgia. (29727.)
- (16) Pottery clay. Lawrence County, Indiana. (29714.)
- (17) Pottery clay. Waco, Madison County, Kentucky. (33975.)
- (18) Pottery clay. Jefferson County, Missouri. (17245.)
- (19) Pipe clay. Westport, Essex County, New York. (20286.)

THE CARBON GROUP.

The series of naturally occurring materials in which carbon forms the chief constituent contains several classes of widely differing materials of much economic importance. Taken as a whole, this group is most naturally and scientifically classified by the increasing amounts of volatile hydrocarbons, which the materials contain or evolve upon being heated. Besides this increasing amount of gaseous constituents, there is also a gradual change in physical characters, beginning with diamond, the hardest of known substances, thence through an increasing softness to liquids, and ending with a gas. This group may be naturally divided into the pure carbon, coal, and bitumen series.

PURE CARBON SERIES.

DIAMOND.

Composition: C. Pure carbon.

It crystallizes in the isometric system, generally with an octahedral habit. The faces are usually curved, and twins are common. It has a very perfect octahedral cleavage. Its hardness is 10, being the hardest substance known. Its specific gravity is 3.5. It is usually white and colorless, but may be tinged many colors. Its luster is characteristic.

The diamond is found mostly in sand, gravel, or clay of recent alluvial formation. The principal localities are in India, South Africa, and Brazil. The principal value of the diamond is as a gem, but small amounts are used for cutting hard materials, and as the cutting edge of drills, especially rock drills.

(1) A single Indian diamond is shown here; further illustrations can be seen in the gem series of the mineral department. (59975.)

GRAPHITE. (PLUMBAGO, BLACK LEAD, CARBURET OF IRON.)

Composition: C. Pure carbon, often containing a small amount of impurity.

It crystallizes in the hexagonal system in tabular forms with basal cleavage. Crystals are rare. It generally occurs in foliated or granular masses. Its hardness is 1 to 2, and specific gravity 2 to 2.2. It is iron-black to steel-gray in color. It is sectile and soils everything it

comes in contact with. It differs from the diamond in being very soft and crystallizing in the hexagonal system. It occurs in the older crystalline rocks.

Graphite is used for a variety of purposes. The manufacture of crucibles and other fire-resisting articles and stove polish consumes two-thirds of the total used. Small amounts are used for lubricators, paint, polishing material, and lead pencils. A single specimen is shown here; others will be found with the manufactured articles.

(1) Coarsely crystalized, in quartz and mica, a characteristic specimen of disseminated ore requiring dressing to separate the graphite from the gangue. Ticonderoga, Essex County, New York. (37825.)

APPLICATION OF GRAPHITE.

The crude graphite and manufactured articles from Bloomingdale, Passaic County, New Jersey, are illustrated by six specimens:

- (1) Sample from main shaft of vein, 20 feet wide. (56272.)
- (2) Dry lubricator, for ordinary machinery. No. 10. (56273.)
- (3) Dry lubricator, for heavy bearings. No. 50. (56274.)
- (4) Brush silver facing, for foundry uses. No. 60. (56275.)
- (5) Stove polish. No. 61. (56276.)
- (6) Very fine, for electrotypers, lead pencils, etc. No. 90. (56277.)

The following specimens illustrate prepared graphite manufactured by the Pennsylvania Mining and Manufacturing Company, Philadelphia, Pennsylvania.

- | | |
|---------------------------------------|--------------------------------------|
| (1) Crucible graphite. (32465.) | (5) Powder glaze. (32463.) |
| (2) Pure lubricating. (32460.) | (6) Pencil graphite. (32466.) |
| (3) Lubricating "Excelsior." (32461.) | (7) Electrotyping graphite. (32464.) |
| (4) Shot glaze. (32462.) | |

The following series of specimens shows three characteristic varieties of graphite from the mines of the Dominion of Canada Plumbago Company, in Buckingham, Province of Quebec, Canada, the material as prepared for various uses and articles manufactured from this graphite, some of which have been subjected to severe practical tests:

- (1) Foliated, characteristic and very handsome. (51007.) Composition:

	Per cent.
Carbon	99.675
Volatile matter	0.178
Ash	0.147

- (2) Columnar and granular, massive. (59976.) Composition:

	Per cent.
Carbon	97.626
Volatile matter	0.594
Ash	1.780

- (3) Disseminated in a decomposed rock. (59977.) Composition:

	Per cent.
Graphite	23.798
Soluble rock matter	21.285
Insoluble rock matter	53.741
Iygroscopic water	1.176

PREPARED GRAPHITE.

- (1) Coarse powder. (51675.)
- (2) For crucibles, coarse. (51608.)
- (3) For crucibles, fine. Varies in ash from 3.638 to 7.645 per cent. (51607.)
- (4) For making stove polish. (51620.)
- (5) For lubricating, contains 7.645 per cent. ash. (51610.)
- (6) For electrotypes use, contains 17.652 per cent. ash. (51611.)
- (7) For making pencils, contains 5.143 to 17.682 per cent. ash. (51612.)
- (8) Paint stock, contains 10.737 per cent. ash. (51615.)
- (9) For powder and shot glazing, contains 10.737 per cent. ash. (51619.)
- (10) For glass-makers. (59613.)
- (11) Founders facings. (59614.)
- (12) Hatters stock. (59616.)
- (13) For organ builders. (59617.)
- (14) For piano makers. (59618.)

MANUFACTURED GRAPHITE.

- | | |
|--------------------------------------|----------------------------------|
| (1) Stove polish, in cakes. (51009.) | (3) Carpenters pencils. (51010.) |
| (2) Lead pencils. (51011.) | |

CRUCIBLES.

- | | |
|-----------------------------|-----------------------------|
| (1) Brass. No. 50. (51003.) | (6) Brass. No. 10. (51600.) |
| (2) Brass. No. 40. (51596.) | (7) Brass. No. 6. (51007.) |
| (3) Brass. No. 30. (51597.) | (8) Brass. No. 1. (51601.) |
| (4) Brass. No. 25. (51598.) | (9) Steel. No. 40. (51004.) |
| (5) Brass. No. 20. (51599.) | |

TESTED CRUCIBLES.

- (1) 150 pounds crucible, used for twenty-six heats by the Birmingham Patent Tube Company. (51006.)
- (2) 120 pounds crucible, used for thirty-six heats of wire metal at Waterloo Works, Birmingham, England. (51603.)
- (3) 60 pounds crucible, used for twenty-two heats at the Cambridge Steel Works, Birmingham, England. (51604.)
- (4) 50 pounds crucible, used for forty-eight heats of brass at the Winfield Works, Birmingham, England. (51605.)

COAL SERIES.**COAL.**

Composition: Various hydrocarbons, with possibly free carbon. Compact and massive, with little or no structure except banding and a jointed fracture.

It varies in hardness from 0.5 to 2.5, and in specific gravity from 1 to 1.8. Is black to brown in color, and varies from dull to submetallic in luster. It breaks with a more or less conchoidal fracture, and is generally brittle. When heated evolves gas, or tarry matters, or both. It is infusible, but many varieties soften on being heated and are more or less decomposed.

Coal occurs as a regular member of the rock series interstratified with

shales, sandstones, conglomerates, and occasionally limestone. It characterizes and gives the name Carboniferous to a geological period, in the rocks of which it occurs. Small amounts, however, are found in the rocks of later periods.

The varieties of coal are ordinarily classified by the increasing amounts of volatile matter which are driven off on being heated, but the classes graduate into each other and sometimes overlap, since the presence of more or less ash may change the per cent. of volatile matter from one class to another. As the volatile matter increases the fixed carbon decreases.

Anthracite contains up to 7 per cent. volatile matter.

Semi-anthracite contains 7 to 10 per cent. volatile matter.

Semi-bituminous contains 10 to 18 per cent. volatile matter.

Bituminous contains over 18 per cent. volatile matter.

While this classification has been in use many years and is convenient, especially for trade purposes, a more rational and scientific classification is by the fuel ratio or the ratio existing between the fixed carbon and the volatile hydrocarbons, or the figure obtained by dividing the per cent. of fixed carbon by the per cent. of volatile hydrocarbon.

This is usually expressed $\frac{C}{VH \cdot C}$. In this classification the water and ash are regarded as impurities, and only the combustible portions of the coal considered. Upon this basis the coals would be defined as follows:

	$\frac{C}{VH \cdot C}$
Anthracite	100 to 12
Semi-anthracite	12 to 8
Semi-bituminous	8 to 5
Bituminous	5 to 0

The bituminous coals are subdivided in a variety of ways, the principal being coking coals, or those that form a coherent cellular coke on being heated, noncoking, that do not form coke, cannel coal, very rich in hydrocarbons, and brown coal or lignite, generally of more recent formation and containing a larger proportion of oxygen.

On being heated with free access of air all coals combine with the oxygen of the air, or burn, with the generation of heat. This generation of heat on burning is the basis of the principal applications of coal, and enormous amounts are consumed for this purpose. On being heated in closed chambers or retorts some varieties of coal, particularly cannel coal, give off large volumes of gas which can be collected and subsequently used for illuminating and heating purposes, and leave a residue of poor coke, which can be used for heating purposes. The coking coals yield a hard strong coke on being thus heated, which is very valuable for metallurgical purposes, but the gas evolved is generally allowed to go to waste. Large amounts are used for this purpose.

The production of coal in the United States in 1889 was 133,000,000 tons.

ANTHRACITE COAL. (GLANCE COAL, STONE COAL.)

Composition: 80 to 94 per cent. fixed carbon, 1.5 to 7.50 per cent. volatile matter, and 4 to 12 per cent. impurities, including water.

It is quite hard and has a high specific gravity 1.3 to 1.75. It has a very bright characteristic luster, and breaks with a conchoidal fracture. Gives a very feeble flame in burning. A remarkable peculiarity is that it is almost impossible to ignite a single piece of anthracite, and if combustion is once fairly started it will cease unless external heat is supplied, so that to start and maintain a fire with this coal it is necessary to have a group of several pieces.

There is a small area of hard dry anthracite in Rhode Island and a second small area of very poor coal in Virginia. By far the largest and most important area is in Pennsylvania, where it underlies 500 square miles, and from which 43,922,879 tons were extracted in 1888.

At the beginning of the coal series stands the hard graphitic anthracite of Rhode Island. This field is quite small, but produces a considerable amount of coal for local consumption. The coal occurs in the oldest Coal Measures, and its hardness and graphitic nature are characteristic. The general composition is indicated by the following analysis, showing wide variations in water and ash:

	<i>Per cent.</i>	<i>Per cent.</i>
Water	8.55	0.24
Volatile matter	3.55	4.49
Fixed carbon	82.25	82.20
Ash	5.65	13.07
Sulphur		0.34
Analysts	Prof. Shaler.	Prof. Gooch.

It is illustrated by two specimens from Newport.

- (1) Graphitic anthracite, Newport, Rhode Island. (59099.)
- (2) Graphitic anthracite, Newport, Rhode Island. (17299.)

The Pennsylvania anthracite is illustrated by complete series of the characteristic varieties. The most important collection is the very complete illustration of the operations of the Philadelphia and Reading Coal and Iron Company at the Kohinoor Colliery, Shenandoah, Schuylkill County, Pennsylvania. This includes roof, coal, bony, and floor; a complete series representing the preparation of the coal for market, including the run of mine, with a 3-ton piece, nine market sizes, and three specimens of breaker waste; a complete set of tools used in the mine and breaker; and a number of views about the mine, including five views in the interior of the mine taken by electric light.

The average composition of the coal from this colliery is—

	<i>Per cent.</i>
Water	3.163
Volatile matter	3.717
Fixed carbon	81.143
Sulphur	0.899
Ash	11.078

This series is one of the most interesting and instructive in the department, and contains forty-eight specimens.

MINE SPECIMENS.

- | | |
|---------------------------------|---------------------------|
| (1) Roof slate. (59063.) | (3) Bony. (59065.) |
| (2) Coal, run of mine. (59062.) | (4) Floor slate. (59064.) |

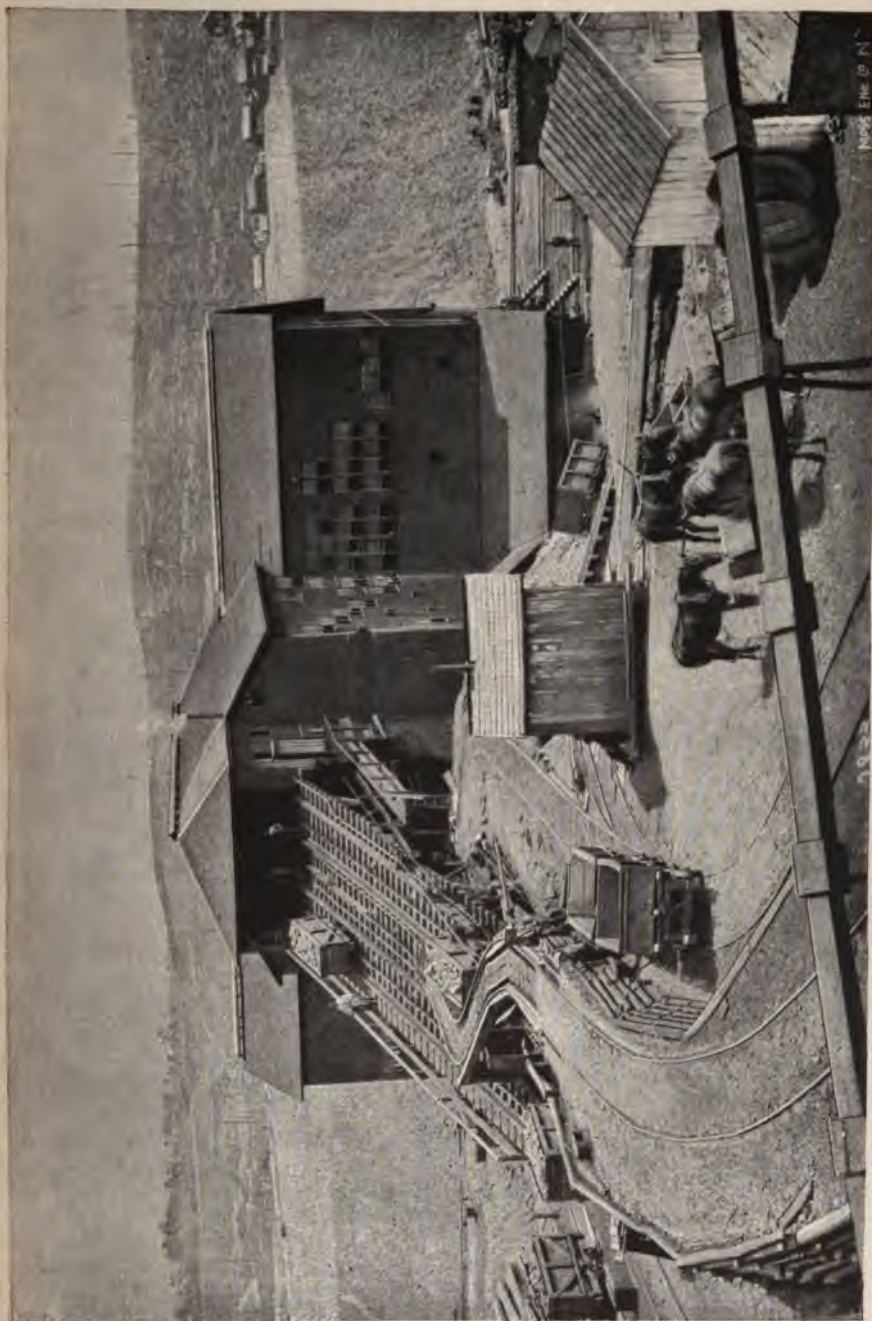
After the coal is extracted from the mine it is prepared for market by being graded according to size in a building called a breaker. The Kohinoor breaker is shown on PL. XXXI. To prepare the smaller sizes the coal is first crushed, then separated into the different sizes by sieves or revolving screens. After this it passes over a series of chutes, where boys and disabled men pick out the pieces of slate and bony coal as shown on PL. XXX. It then passes to pockets, whence it is loaded on the cars for shipment. A breaker is generally arranged so that the coal is delivered at the top of the building, and then travels downwards by gravity through the successive steps until it is loaded on the cars.

BREAKER SPECIMENS.

- | | |
|--|---|
| (1) Coal, run of mine, 3-ton specimen.
(59974.) | (8) Chestnut. (59052.) |
| (2) Lump or furnace. (59058.) | (9) Pea. (59051.) |
| (3) Steamboat. (59057.) | (10) Buckwheat. (59050.) |
| (4) Broken. (59056.) | (11) Breaker waste, dust. (59059.) |
| (5) Egg. (59055.) | (12) Breaker waste, slate. (59060.) |
| (6) Large stove. (59054.) | (13) Breaker waste, bone. (59061.) |
| (7) Small stove. (59053.) | (14) Iridescent anthracite, commonly
called peacock coal. (59086.) |

TOOLS.

- (1) Torch lamp, tin, with two spouts; used as a stationary lamp in the gangways or breakers. (59188.)
- (2) Mule lamp, tin, with sheet-iron shield; a large lamp with lift-top and large spout. It is suspended from the collar of the leading mule as a guide for the mules following. (59165.)
- (3) Driver's cadger, a small tin can used by the miners and drivers for carrying oil for their lamps. (59184.)
- (4) Miners cotton, a ball of ordinary wick, commonly called "cotton" by the miners. Used in the miners lamps. (59190.)
- (5) Mining pick, a common form used in the anthracite mines. (59166.)
- (6) Bottom pick, used about the anthracite mines, mainly in breakers for breaking coal and slate, and separating the same. (59167.)
- (7) Coal drill or jumper, used for drilling blasting holes in the coal by jumping it up and down. (59169.)
- (8) Rock drill, used for driving tunnels and gangways. (59170.)
- (9) Iron scraper, used for cleaning out loose dirt in drill-holes. (59172.)
- (10) Copper needle, used to insert the cartridge into the drill-hole, where it remains until the hole is tamped, when it is withdrawn, leaving a small hole for the insertion of the exploder. Made of copper to prevent striking fire. (59171.)
- (11) Blasting barrel, used in making a shot in damp places. (59173.)
- (12) Fuses or squibs, made by the miners for exploding cartridges. (59179.)
- (13) Miners safety squibs. Daddow & Beadle's patent rocket squib. Used for exploding cartridges. (59180.)



BREAKER AT KOHINOOR COLLIERY SCHUYLKILL COUNTY, PENNSYLVANIA.
(See explanation, page XVIII.)

- (14) Oil or powder can, used by the miners for carrying either oil or powder into the mines. (59181.)
- (15) Cartridge stick, used by the miners in making shells for cartridges. (59178.)
- (16) Blasting paper, a water-proof paper used by the miners for manufacturing cartridges. (59186.)
- (17) Rosin soap, used with blasting paper for making cartridges. (59187.)
- (18) Powder keg, sheet iron; form used at these collieries. (59182.)
- (19) Coal wedge, cast steel; a common form of wedge used with the sledge. (59175.)
- (20) Sledge hammer, cast steel: the form used for driving wedges in the coal at these collieries. (59174.)
- (21) Mining shovel, cast steel, short handle. Used in the mine for loading the smaller pieces of coal into mine wagons. (59176.)
- (22) Coal rake, a six-pronged iron rake; used in the breasts for manipulating the coal. (59168.)
- (23) Miner's dinner can. (59185.)
- (24) Water or tea bottle, with chain; used for carrying water or tea into the mine. (59183.)
- (25) Breaker rake, a two-pronged rake; used by the platform men in the breaker for manipulating the coal as it comes from the mine. (59191.)
- (26) Breaker scraper, used for removing obstructions in the chutes. (59192.)
- (27) Scoop shovel, cast steel; used in and about the breaker and dirt pile. (59177.)
- (28) Breaker platform pick, used for breaking the coal, and also for detaching the slate and rock. (59195.)
- (29) Breaker eye wedge, handled; used with the sledge by the platform men for breaking large lumps of coal as it comes from the mine; peculiar to the Ellangowan Colliery. (59194.)
- (30) Breaker wire broom, used in the breaker for cleaning the revolving screens when the meshes are filled with wet coal. (59193.)

VIEWS.

The interior of breast No. 39 is illustrated by the following five photographs, taken by electric light August 28 and 29, 1884. This breast was selected because it shows 42½ feet of coal, and the process of robbing the mine or taking out the roof and pillars of coal left when the mine was first opened was going on then. It is under the edge of Shenandoah City, about 500 feet vertically below the surface:

(1) Entrance to the breast. At the left, in the background, is a pillar of coal, left to support the roof. In front of this is the mine railway. In the center, in the background, is the entrance to the breast, with the roof (at this place the 5-foot bench) supported by timber props. On the right, in the background, is another pillar of coal; in front of this is a pile of refuse or "gob;" and in front of this, again, are some worn-out timber props. A man, standing in the entrance, furnishes a measure of the height of the gangway. (59009.)

(2) Has the face of the breast for a background, showing especially the lower benches of the formation and the slate partings. A man on the left (whose complexion, by the way, is given with evident accuracy) is breaking down the coal with a pick, one in the center is loading the lump coal on a mine car with a shovel, and one on the right is drilling a hole for a blast with the old fashioned hand drill or "jumper." The scraper for removing the drill dust from the hole and the needle for the introduction of the cartridge lean against the face of the breast in front of the middle man. (59006.)

(3) Shows nearly the same background as No. 59006. A miner is drilling a hole in the 7-foot bench for a blast with a modern patent drill and by the light of the safety lamp, various tools being grouped about him. (59008.)

(4) Shows on the right in the foreground the corner of a pillar of coal, which exhibits in great perfection the banded structure of the formation. Near the center are two miners in characteristic positions at work removing the pile of coal that has been thrown down by the blast in robbing the mine. At the left, in the background, is the face of the breast, which has been squeezed or crushed by pressure, as is shown by the confused appearance of the strata. (59007.)

(5) Electric-light plant used for photographing, located at the intersection of the long slant gangway and east lift. (59010.)

The following four specimens are from the Primrose vein, Primrose Landing, 1,575 feet from the surface:

The average composition of this coal is:

	Per cent.
Water	3.541
Volatile matter	3.716
Fixed carbon	81.590
Sulphur	0.499
Ash	10.654

(1) Coal, red ash. (59090.)

(3) Slate. (59093.)

(2) Bony coal. (59094.)

(4) Bastard slate. (59092.)

The following are general illustrations of anthracite:

(1) Coal, white ash. Taken from Mammoth Vein, Diamond Landing, 1,131 feet below the surface. (59091.)

(2) White ash, from an anticlinal axis near the surface. (59088.)

(3) Sandstone, from an anticlinal axis near the surface. (59087.)

(4) View of a breach in the Kaska-William Colliery, Schuylkill Valley Basin, east end of Mine Hill; elevation, 1,012 feet above tide at Philadelphia. Anticlinal axis, showing coal and rock. (59020.)

(5) Coal, red ash, taken from the top of a small anticlinal. Shows the curvature of the formation by the outline and cleavage of the specimen; about 50 feet below the surface. Palmer Vein Colliery, New Philadelphia, Schuylkill County, Pennsylvania. (59089.)

(6) Iridescent anthracite, commonly called peacock coal. Ross Vein Mine, Wilkes-Barre, Luzerne County, Pennsylvania. (59085.)

(7) Coal, white ash. A cube 10 by 10 inches, taken from the Mammoth Vein, Keeley Run Colliery, Shenandoah, Schuylkill County, Pennsylvania. (59110.)

(8) Coal. A cube 4 by 4 by 4 inches, taken from the Mammoth Vein (Top Split); contents 64 cubic inches; weight $3\frac{1}{2}$ pounds, equivalent to $2,574\frac{3}{4}$ pounds or 1.149 tons per cubic yard. Hammond Colliery, Girardville, Schuylkill County, Pennsylvania. (59109.)

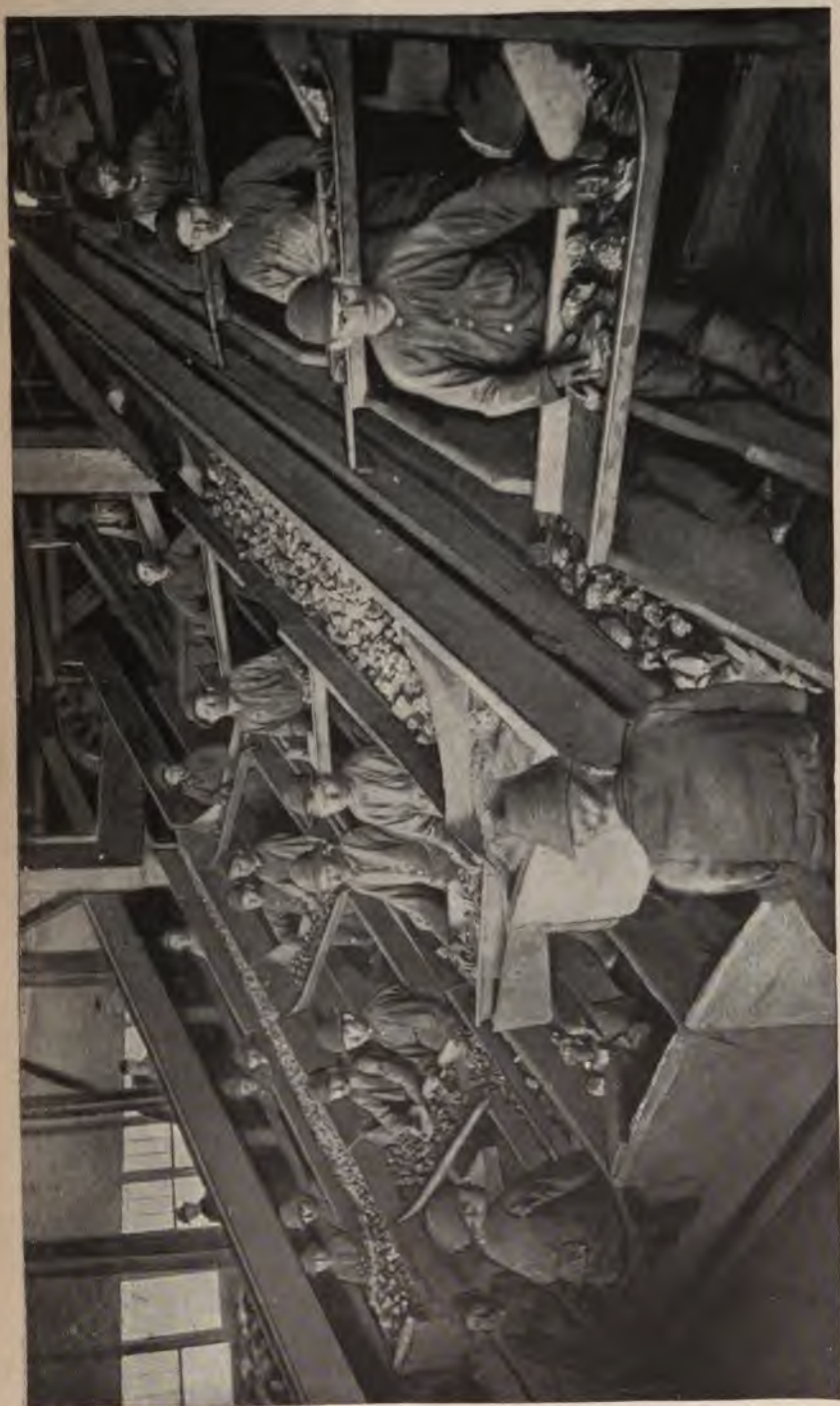
(9) Model of the Panther Creek Coal Basin, showing the outline, area, and form of the coal bed and the portions which have been worked out. Prepared under the directions of Dr. Chas. A. Ashburner. (59980.)

As an evidence that the miner is artistic, and to show the adaptability of anthracite coal for art objects, three ornaments cut from it are shown. The lady's slipper is particularly effective as an art product.

(1) Lady's slipper, made by a miner from anthracite coal. Kohinoor Colliery Shenandoah, Schuylkill County, Pennsylvania. (59117.)

(2) Caster and cruets, cut by a miner from anthracite coal. Ellangowan Colliery, Shenandoah, Schuylkill County, Pennsylvania. (59066.)

(3) Miner's brogan. (59108.)



PICKING SLATE AND BONY COAL, ELLANGOWAN COLLIERY.
(See explanation, page XVIII.)

The action of mine water upon iron is illustrated by two specimens:

(1) Iron bolts. Taken from the bottom of an iron tank used for hoisting mine water to the surface. The original size was 7½ inches by three-quarters of an inch; the cotton waste on the bolt was used to exclude the water. They are now eaten away to a shred. Kohinoor Colliery, Shenandoah, Schuylkill County, Pennsylvania. (59096.)

(2) Miner's pick. Was submerged about 20 years, during the flooding of the Kaska-William Colliery. New Philadelphia, Schuylkill County, Pennsylvania. (59135.)

The outfit worn by a miner in the anthracite mines of Schuylkill County, Pennsylvania, is illustrated by the following old suit:

- | | |
|------------------------|--------------------------------|
| (1) Boots. (59128.) | (8) Water bottle. (59134.) |
| (2) Pants. (59126.) | (9) Pick. (59129.) |
| (3) Overalls. (59127.) | (10) Hand drill. (59130.) |
| (4) Shirt. (59125.) | (11) Scraper. (59131.) |
| (5) Vest. (59124.) | (12) Needle. (59132.) |
| (6) Hat. (59123.) | (13) Blasting barrel. (59133.) |
| (7) Lamp. (59122.) | |

Five characteristic fossils are shown:

(1) Slate, with fern impressions. Kohinoor Colliery, Shenandoah, Schuylkill County, Pennsylvania. (59116.)

(2) Stigmaria, from the anthracite coal measures. Pottsville, Schuylkill County, Pennsylvania. (59119.)

(3) Algæ, from the red shale immediately under the conglomerate of the anthracite coal measures. Pottsville, Schuylkill County, Pennsylvania. (59120.)

(4) Calamite, from the anthracite coal measures. Pottsville, Schuylkill County, Pennsylvania. (59121.)

(5) Lepidodendron, underlying the Buck Mountain bed. Mine Hill Gap, Schuylkill County, Pennsylvania. (59112.)

The following series of specimens illustrate the open lamps in use in the Wyoming Valley Region, Luzerne County, Pennsylvania:

(1) Superintendent or boss miner's lamp, made of copper, as this metal does not attract the needle of the compass. (59073.)

(2) Superintendent or boss miner's lamp, larger than the ordinary mining lamp, with a large hook to be used as a handle. (59074.)

(3) With stationary tank, in which cheap kerosene oil may be burned. (59075.)

(4) With an adjustable tank, in which cheap kerosene oil may be burned. (59076.)

(5) With lift top, in which the lowest grade of kerosene oil, or a better quality known as patent oil, may be burned. (59077.)

(6) Patent-oil lamp, with screw top. (59080.)

(7) Preferred by the miners of the Wyoming Valley region to any other kind in which cheap kerosene oil is burned. (59078.)

(8) Open, for burning only the cheapest grades of kerosene oil. (59079.)

(9) Open, for burning either whale or cotton-seed oil. (59081.)

(10) The same as 59081, differs slightly in shape. (59082.)

(11) Brass, with match box inside, striker at the bottom, and picker near the hook. (59084.)

Two specimens illustrate the open lamps used in the New River, Gauley, and Kanawha districts of West Virginia. From the Sewell Mine, Sewell, Fayette County, West Virginia. They are shown with the anthracite lamps for comparison.

(1) With lift top and double spout. (59214.)

(2) With lift top, in which linseed oil may be burned. (59213.)

The following series of safety lamps, presented by Messrs. J. W. Queen & Co., Philadelphia, Pennsylvania, illustrate the principal forms of such lamps:

- (1) Clanny, has an iron-wire gauze and a glass globe surrounding the wick so arranged as to obtain the best light possible. (59266.)
- (2) Newcastle Davy, fitted entirely with iron-wire gauze. It has a large bottom and is provided with a hook at the top to suspend the lamp from. (59267.)
- (3) Newcastle Davy, with the attachment of William's patent extinguisher. (59268.)
- (4) Fireman's lamp, embodying the principal of a Davy lamp, inclosed with iron-wire gauze. It has a foot of small diameter and can be fixed by a hook to the wall and hang perfectly straight so that the flame can be kept in the center. (59269.)
- (5) Boss fireman's lamp, of the same style of the one used by the fireman. It is smaller, to be conveniently carried, and is also better finished than the assistant's lamp. (59270.)
- (6) Newcastle Davy, same as the preceding, but heavier. (59271.)
- (7) Stephenson lamp, fitted with iron-wire gauze, with a glass tube inside. (59272.)
- (8) Muesler lamp with a glass globe. It closely resembles the Clanny lamp, excepting that it has a metal funnel in the gauze and a horizontal piece of gauze over the flame. Used particularly in Belgium. (59273.)

The following views represent characteristic scenes about different mines and breakers:

- (1) Interior of engine house, showing the deep shaft hoisting engine, cable and drum. The most complete hoisting apparatus in the anthracite coal districts. Deep shaft colliery, Pottsville, Schuylkill County, Pennsylvania. (59011.)
- (2) Shenandoah City slope, taken from tip house, showing the mouth of the slope, with a barney used in hoisting mine wagons, also the manway. Shenandoah City colliery, Shenandoah, Schuylkill County, Pennsylvania. (59014.)
- (3) Coal plane, over which coal is hoisted from drifts to breaker; steam cables and steam hoisting apparatus; tip-house at head of plane, and barney house at foot; loaded car going up, and "empty" coming down. The mule and driver, whose duty it is to haul the mine wagons to the foot of the plane, appear near the barney house. Shenandoah City colliery, Shenandoah, Schuylkill County, Pennsylvania. (59012.)
- (4) Head frame, showing the apparatus over the mouth of the shaft for supporting the hoisting coil; also a loaded mine wagon as it appears on the surface. Ellangowan colliery, Shenandoah, Schuylkill County, Pennsylvania. (59015.)
- (5) Kohinoor colliery breaker, Shenandoah, Schuylkill County, Pennsylvania. (59143.) (See PL. XXXI.)
- (6) Ellangowan colliery breaker, taken from the top of head frame, showing the coal and dirt planes. Shenandoah, Schuylkill County, Pennsylvania. (59016.) (See PL. XXIX.)
- (7) Ellagowan colliery breaker, exterior end and front view of breaker, showing coal pockets, railroad, and the manner of loading coal for market. Shenandoah, Schuylkill County, Pennsylvania. (59140.)
- (8) Interior of Ellangowan colliery breaker, showing the platform men at work on the coal as it comes from the mine. Shenandoah, Schuylkill County, Pennsylvania. (59017.)
- (9) Group of slate pickers, showing a group of boys and disabled men engaged in picking pieces of slate and bony coal from the broken material as it descends the chutes from the breakers to the pockets. Ellangowan colliery, Shenandoah, Schuylkill County, Pennsylvania. (59018.) (See PL. XXX.)
- (10) Barnum colliery breaker. Pittston, Luzerne County, Pennsylvania. (59098.)



BREAKER AT ELLANGOWAN COLLIERY SCHUYLKILL COUNTY, PENNSYLVANIA.
(See explanation, page XVII.)

- (11) William Penn colliery breaker, West Mahanoy, Schuylkill County, Pennsylvania. (59142.)
 (12) Lost Creek colliery breaker, Lost Creek, Schuylkill County, Pennsylvania. (59141.)
 (13) Mahanoy coal plane, Mahanoy, Schuylkill County, Pennsylvania. (59144.)
 (14) Group of mining superintendents and engineer in working costume. (59013.)

SEMI-ANTHRACITE COAL. (FREE BURNING COAL).

Composition: 74 to 90 per cent. fixed carbon, 7 to 14 per cent. volatile matter, and 2.5 to 12 per cent. impurities, including water.

It is not so hard or dense as anthracite, nor so bright. The fracture on breaking is nearly cubic. When first ignited it gives a flame which soon dies out. It is found principally in the western end of the Pennsylvania anthracite fields.

The semianthracites are illustrated by a series of specimens from the Loyal Sock mine, Bernice, Sullivan County, Pennsylvania, together with a complete set of tools. The following analyses represent the average composition of the coal from this mine:

	<i>Per cent.</i>	<i>Per cent.</i>
Water	1.953	1.295
Volatile matter	9.630	8.100
Fixed carbon	80.143	83.344
Sulphur	0.629	1.031
Ash	7.645	6.230

MINE SPECIMENS.

- (1) Sandstone, roof of the top bench. (59162.)
 (2) Fire clay, top, with fern impressions. (59146.)
 (3) Coal. (59145.)
 (4) Slate, parting between the middle and upper benches of B beds. (59161.)
 (5) Floor slate. (59147.)
 (6) Mineral charcoal, sometimes called "mother of coal." (59163.)
 (7) Stigmara. (59164.)
 (8) Iridescent semi-anthracite, commonly called peacock coal. (59203.)

TOOLS.

- (1) Mining lamp, tin, lift top, double spout, in which cotton-seed or lard oil may be burned. (59197.)
 (2) Miners cotton, a ball of ordinary wick, commonly called "cotton" by the miners. (59198.)
 (3) Mining pick, the common form used at this mine, with private mark of miner. (59148.)
 (4) Bottom pick, used in this and the Long Valley mines, and also outside at breaker. (59149.)
 (5) Steel hand drill or jumper, used for drilling blasting holes in coal by jumping it up and down. (59150.)
 (6) Iron scraper, used for cleaning out loose dirt in drill holes. (59153.)
 (7) Iron needle, used for inserting the cartridge into the blasting hole, and to leave a passage way for the squib used in firing the shot. (59152.)
 (8) Iron blasting barrel, used in making a shot in damp places. The wire is for removing obstructions in the barrel. (59160.)

- (9) Squib box, used for carrying fuses or squibs in the mines for firing the shots. (59204.)
- (10) Steel wedge, used in breaking up the coal. (59196.)
- (11) Sledge, form used in this mine for driving the wedge into the coal. (59151.)
- (12) Scoop shovel, used inside of mine for loading mine wagons. (59156.)
- (13) Miner's ticket, placed upon each car loaded by a given miner in order to get proper credit for his work. (59201.)
- (14) Ticket hook, to be fastened to the bottom of the coal car, and used to hold the ticket of the miner getting out the load. (59202.)
- (15) Sprag, new, oak, cigar shaped, 18 by 2 inches; used instead of a break by thrusting it between the spokes of the mine wagon wheels. (59154.)
- (16) Sprag, old, cigar shaped, 18 by 2 inches; used instead of a brake by thrusting it between the spokes of the mine wagon wheels. (59155.)
- (17) Mine railway spike, form used for the mule road or tramway. (59200.)
- (18) Hand ax, a short-handled ax used for making cap pieces. (59157.)
- (19) Cap piece, wedge of wood driven in between the prop and roof, in breast of mine, to fasten the prop. (59158.)

SEMI-BITUMINOUS COAL.

Composition: 68 to 77 per cent. fixed carbon, 11 to 17 per cent. volatile matter, and 7 to 13 per cent. impurities, including water.

There is little in the physical character to distinguish the semi-bituminous from the true bituminous, except by an expert. On burning they yield a larger and more permanent flame than the semi-anthracite, but a shorter flame than the bituminous. Considering that they grade insensibly into the bituminous, it is to be expected that they would not differ materially in physical characters. They are liable to be found in any bituminous field, and have been largely mined in most of our bituminous areas.

The semi-bituminous coals are illustrated by three collections.

From the Long Valley Mine, Barclay, Bradford County, Pennsylvania, are shown a section of the vein, with a few accessories, and three characteristic photographs.

The coal is of the following composition:

	Per cent.
Water	1.990
Volatile matter	18.530
Fixed carbon	67.423
Sulphur	1.742
Ash	10.315
	<hr/>
	100.000
Phosphorous	0.0061

- (1) Top slate. (59070.)
- (2) Coal, top, from south gangway. (59068.)
- (3) Coal, top, from main west gangway. (59069.)
- (4) Coal, bottom. (59067.)
- (5) Fire clay, bottom. (59071.)
- (6) Oak sprag, used instead of a brake by thrusting it between the spokes of the mine wagon wheels, both in and outside of mine. (59072.)



MINE WAGONS EN ROUTE FROM MOUTH OF DRIFT TO CHUTES.
(See explanation, page XVIII.)

VIEWS.

(1) A mule trip, a train of mine wagons hauled by a mule as it appears from the mouth of the drift on the way to the chutes. (59106.) (See PL. XXXII.)

(2) Group of miners, in their working costumes as they emerge from the mouth of the drift on their way home. (59105.) (See PL. XXXIII.)

(3) Coal plane, from foot. Used in transferring coal down the side of the mountain to market. (59104.) (See PL. XXXIV.)

From the Arnot Mine, Arnot, Tioga County, Pennsylvania, are shown the coal and associates, together with some characteristic tools:

(1) Top Rock. (59248.)

(2) Fire clay, taken from the roof. (59249.)

(3) Iridescent coal, commonly called peacock coal. (59246.)

(4) Bony coal, found in the coal about 18 inches from the bottom of No. 2 drift. (59247.)

(5) Bottom rock. (59250.)

(6) Fossil, found in sandstone. (59244.)

(7) Fossil, found in bottom fire clay. (59243.)

(8) Anchor pick. (59236.)

(9) Bottom pick. (59237.)

(10) Rock drill, a ratchet drill or "ricketty," made by the mine blacksmith and used for boring holes in the solid rock for a "shot." (59240.)

(11) Hand sprag, a long sprag, used instead of a brake on mine wagons by thrusting it between the spokes of the wheels. (59239.)

(12) Sprag, used instead of a brake on mine wagons by thrusting it between the spokes of the wheels. (59238.)

(13) Mule rail, a foot of 16-pound T rail, height, 1½ inches. (59241.)

(14) Engine rail, a foot of 35-pound T rail, height, 3 inches; brought into use since the introduction of locomotives. (59242.)

From Fall Brook Mine, Antrim, Tioga County, Pennsylvania, are shown a section of the vein and the outfit used by the miner:

(1) Top rock. (59227.)

(3) Bottom rock. (59226.)

(2) Coal. (59225.)

The outfit worn by a miner in the semi-bituminous mines is illustrated by the following new suit:

(1) Wool half hose. (59038.)

(2) Brogans, heavy double-soled, full Hungarian nailed. (59039.)

(3) Pantaloon overalls, made of white cotton duck. (59037.)

(4) Woolen overshirt. (59041.)

(5) Sack coat, made of heavy blue denim. (59040.)

(6) Water-proof hat, with ear laps and lamp-holder. (59042.)

(7) Lamp, with double spout and lift top. (59044.)

(8) Oil can. (59036.)

(9) Pocket oil flask. (59043.)

(10) Dinner can. (59047.)

(11) Water bottle, with screw top. (59045.)

(12) Squib box. (59046.)

(13) Steel pick. (59048.)

BITUMINOUS COAL.

Composition: 35 to 70 per cent. fixed carbon, 18 to 60 per cent. volatile matter, and 2 to 20 per cent. and, in exceptional cases, even 30 per cent. of impurities, including water.

The coals included under this head vary greatly in composition and physical characters. In general they are soft and dull in luster as compared with anthracite. Some of the cannel coals are almost sectile, and are earthy in luster.

The specific gravity varies, but does not rise above 1.5. The fracture varies from conchoidal to cubic. They kindle easily and burn with a long, yellow, and sometimes smoky flame. Bituminous coals are subdivided in several ways, and the following are the principal divisions: Coking, non-coking, cannel, and brown coal or lignite.

Coking coals are soft and have a nearly cubic fracture. They give a long, yellow flame in burning and make a hot fire. Their chief characteristic, however, is that they soften when first heated, and yield a hard, sonorous, cellular coke on continued heating.

Noncoking coals are bituminous coals, which do not yield a good coke on heating. They are divided into two principal varieties, cherry and splint. Cherry coal generally has a bright luster, but may be dull. It is very black and breaks easily into cubic masses. It ignites easily, burns with a yellow flame, and makes a hot fire. When left undisturbed pieces retain their shape until entirely consumed. Its specific gravity is 1.20 to 1.30. Splint coal is dull black. It is harder and stronger than cherry, and has a slaty structure. It breaks readily lengthwise, but has a conchoidal cross fracture. It does not kindle easily and makes a dull fire, requiring care in its management. Its specific gravity varies from 1.25 to 1.40.

Between the coking and non-coking coals there is frequently no chemical difference as shown by the ordinary methods of analysis. There is evidently some chemical difference, but it is not well understood.

Cannel coal varies from gray to black. It is dull to resinous in luster with a slaty structure, and breaks with a conchoidal fracture. It kindles easily and gives a long, yellow flame, which is frequently smoky. Pieces of it once ignited burn like a candle, whence its name. Its chief characteristic is the large amount of volatile matter that is given off on heating. On this account it is particularly valuable for gas making, and was formerly considered essential for that purpose. Formerly it was also used for the distillation of oils, but has now been replaced by petroleum. Cannel coal frequently contains a large percentage of ash.

Brown coal, as its name indicates, is brownish-black in color. It is brittle and breaks with a cubic fracture. It burns easily and makes a good fire. It is more highly oxygenated than any of the other coals and contains 15 to 30 per cent. of oxygen. It occurs in formations more recent than the carboniferous. Lignite is a variety of brown coal which still retains its woody structure.

The typical coking coal of this country is that of the Connellsville basin of the Pittsburgh bed in Pennsylvania. The coal and the coke made from it are represented by the following analyses:



MINERS IN WORKING COSTUME.

(See explanation, page XVIII.)

	Coal.	Coke.
	<i>Per cent.</i>	<i>Per cent.</i>
Water.....	1.105	0.030
Volatile matter.....	20.885	0.460
Fixed carbon.....	57.754	89.576
Ash.....	9.895	9.113
Sulphur.....	1.339	0.821
	100.00	100.00

Analyst, McCreath.

This coal is illustrated by a complete series from the H. C. Frick Coke Company, showing a section of the vein, metallurgical coke, and domestic coke in several sizes.

COAL MINE.

- (1) Rock, above coal. (55493.) (4) Binder, 5 feet. (55492.)
 (2) Bituminous coal, run of mine. (55490.) (5) Rock, horseback. (55494.)
 (3) Binder, 3 feet. (55495.) (6) Rock, under coal. (55491.)

COKE.

In large pieces as drawn from the oven.

- (1) Forty-eight-hour coke, made in beehive ovens; used for the reduction and melting of iron and other metals. November, 1884. (55484.)
 (2) Seventy-two-hour coke, made in beehive ovens; used for the reduction of iron and other metals. November, 1884. (55483.)

The following five specimens represent the sizes as prepared by crushing and washing for general uses:

- 1) Egg. November, 1884. (55480.) (4) Pea. November, 1884. (55485.)
 2) Stove. November, 1884. (55488.) (5) Nut. November, 1884. (55486.)
 3) Small stove. November, 1884. (55487.)

The coking coals of the New River, West Virginia, region are represented by a series of specimens from the Stone Cliff Mine at Stone Cliff, Fayette County, West Virginia. The composition of the coal and coke made from it are represented by the following analyses:

	Coal.	Coke.
	<i>Per cent.</i>	<i>Per cent.</i>
Water.....	0.50	.....
Volatile matter.....	26.50	.....
Fixed carbon.....	71.00	.....
Sulphur.....	0.50	.....
Ash.....	1.50	.....
	100.00	.....

The collection shows the average coal and a cross-section of the vein.

- (1) Bituminous coal, average specimen. (59260.) (3) Bituminous coal, top. (59256.)
 (2) Fire clay, roof. (59258.) (4) Bituminous coal, bottom. (59257.)
 (5) Floor slate. (59259.)

The coking coals of the Kentucky and Tennessee region are represented by four specimens of coal and one of coke.

(1) Peach Orchard Mine, Lawrence County, Kentucky. (56981.) Composition:

	Coal.			Coke.
	1. 295	1. 325	1. 287	
Specific gravity.....	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Water.....	3. 20	3. 30	3. 90	5. 10
Volatile matter.....	37. 74	22. 70	36. 80	0. 90
Fixed carbon.....	55. 06	64. 46	56. 30	90. 06
Ash.....	4. 00	9. 54	3. 00	3. 94
	100. 00	100. 00	100. 00	100. 00
Sulphur.....	0. 720	1. 132	0. 756	

(2) Captain Crogan's Mine, Pulaski County, Kentucky. (56295.) Composition:

	Coal.			Coke.
	1. 236		1. 368	1. 988
Specific gravity.....	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Water.....	2. 20	1. 40	1. 84	1. 600
Volatile matter.....	36. 20	36. 74	33. 06	
Fixed carbon.....	53. 94	50. 24	58. 16	92. 00
Ash.....	7. 66	11. 62	7. 44	6. 40
	100. 00	100. 00	100. 00	100. 00
Sulphur.....	0. 742	1. 201	0. 555	0. 665

(3) Glen Mary, Scott County, Tennessee. (56367.) Composition:

	Coal.
	<i>Per cent.</i>
Water.....	1. 67
Volatile matter.....	24. 53
Fixed carbon.....	61. 66
Ash.....	2. 14
	100. 00
Sulphur.....	0. 88
Phosphorus.....	0. 039

Analyst, Dewey.

(4) Rockwood, Roane County, Tennessee. (54532.) Composition:

	Coal.
	<i>Per cent.</i>
Water.....	1. 75
Volatile matter.....	26. 62
Fixed carbon.....	60. 11
Ash.....	11. 52
	100. 00
Sulphur.....	1. 49

Analyst, Dewey.



COAL PLANE; LOADED CAR DESCENDING AND EMPTY CAR ASCENDING SIDE OF MOUNTAIN.
(See explanation, page XVIII.)

The variety of non-coking bituminous coal, called cherry, is represented by a single specimen.

- (1) Block coal. Carbon Mine, Clay County, Indiana. (59423.) Composition:

	Per cent.
Water	3.5
Volatile matter	32.5
Fixed carbon	61.5
Ash	2.5
	<hr/> 100.00

The splint variety of non-coking bituminous coal is represented by two collections.

A section of the Crescent Mine, Crescent, Fayette County, West Virginia, shows:

- | | |
|---------------------------|------------------------------------|
| (1) Slate, top. (59210.) | (4) Fire clay, bottom. (59209.) |
| (2) Gas coal. (59207.) | (5) Sulphur, iron pyrite. (59211.) |
| (3) Splint coal. (59208.) | |

The Winifrede Mine, Kanawha County, West Virginia, is represented by:

- | | |
|----------------------------|-------------------------|
| (1) Coal, top. (59252.) | (3) Fire clay. (59254.) |
| (2) Coal, bottom. (59253.) | |

The cannel coals are represented by specimens from West Virginia, Kentucky, and Indiana.

- (1) Cannelton Mine, Kanawha County, West Virginia. (59435.) Composition:

	Per cent.
Volatile matter	58.00
Fixed carbon	23.50
Ash	18.50
	<hr/> 100.00

- (2) Frozen Creek Mine, Breathitt County, Kentucky. (56291.)
 (3) Hunnewell Mine, Greenup County, Kentucky. (56282.)
 (4) Near Ely's, Knox County, Kentucky. (56280.)
 (5) Means & Russell Mine, Everman's Creek, Carter County, Kentucky. (56293.)
 (6) Buena Vista Furnace Mine, Boyd County, Kentucky. (56284.)

Kentucky Cannel Coal.

	56, 291	56, 282	56, 280	56, 293	56, 284
Specific gravity	1.180	1.306	1.300	.....	1.300
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Water	1.20	1.50	2.00	.....	3.20
Volatile matter	58.80	52.20	35.00	.....	32.30
Fixed carbon	35.30	40.60	56.70	.....	53.00
Ash	4.70	5.70	6.30	.....	11.50
	100.00	100.00	100.00	.....	100.00
Sulphur .....	.....	0.780	1.091	.....	1.999

(7) Buckeye Cannel Coal Company, Daviess County, Indiana. (59990.) Composition :

	Per cent.
Water	3.0
Volatile matter	51.0
Fixed carbon	40.0
Ash	6.0
	<hr/> 100.0

The occurrence of two varieties of bituminous coal in one vein is illustrated by a section of the Paint Creek Mine, Paint Creek, Kanawha County, West Virginia.

- | | |
|---------------------------------|----------------------------|
| (1) Sandstone. (54233.) | (4) Splint coal. (54236.) |
| (2) Roof, gray slate. (54234.) | (5) Cannel coal. (54237.) |
| (3) Roof, black slate. (54235.) | (6) Bottom slate. (54238.) |

The brown coals are represented by six specimens.

(1) Aetna mine, Chesterfield County, Virginia. (59262.) Composition :

	Per cent.
Volatile matter	23.80
Fixed carbon	66.60
Ash	4.60

Analyst, Clemson.

100.00

(2) Deep River, Chatham County, North Carolina. (56334.) Composition :

	Per cent.	Per cent.
Water	1.79	1.95
Volatile matter	29.56	30.54
Fixed carbon	58.30	58.47
Ash	7.46	6.85
Sulphur	2.89	2.19
	<hr/> 100.00	<hr/> 100.00

(3) Eastland County, Texas. (56551.)

(4) Lignite, showing traces of the original woody structure. Golden Colliery, Golden, Jefferson County, Colorado. (4795.)

(5) Lignite, showing distinctly the original woody structure. Lower Potomac formation. From log imbedded in the bank of the Dutch Gap Canal 20 miles below Richmond, Virginia. (59978.)

(6) Lignite, showing distinctly the original woody structure. Lower Potomac formation. From near Dutch Gap Canal, Virginia. (59979.)

PEAT. (TURF.)

Closely connected with the coals and in fact forming the end of the series stands peat. This is a bog or marsh formation of very recent origin. It consists of the remains of sphagnum mosses which have the property of dying at the roots as they grow upwards. In this way immense deposits have been formed. By the pressure of the moss and by gradual changes the material is converted into a brownish black, imperfect coal, retaining many evidences of the original vegetation. It

frequently contains large amounts of mineral matter, mainly sand that was blown onto the growing moss. Large deposits are found in Ireland. It is used as a fuel and also as a fertilizer. Although its fuel value is low, when it occurs in regions destitute of other fuels it becomes very useful. This is the case in several northern countries.

Peat is illustrated by a single specimen from a northern island where there is no coal or wood, driftwood being the only fuel for the natives.

(1) Commander Island, Behring Sea, east of Kamohatka. (59320.)

The thoroughly air dried material showed on analysis:

	Per cent.
Water.....	7.60
Volatile matter.....	51.97
Fixed carbon.....	22.06
Ash.....	18.37
	<hr/> 100.00

Analyst, Dewey.

BITUMEN SERIES.

Under this head is grouped the series of hydrocarbons beginning with the solid asphaltum and following through semi-solids to liquid petroleum and ending with natural gas. The members of this series consist of mixtures of various hydro-carbons, many of which contain much oxygen. The solids naturally graduate into the liquids and the liquids frequently change into the solids through the loss of volatile constituents, and sometimes by the absorption of oxygen.

The physical condition is often affected by temperature, and a specimen that is solid in winter may be semi-solid or even liquid in summer. Most of the specimens, particularly of the solids, are black or dark colored; but many of the petroleums are light colored, while natural gas is generally colorless.

SOLID BITUMENS.

ASPHALTUM.

Composition: A mixture of various hydrocarbons.

It is amorphous, and the specific gravity varies from 1 to 1.8 or more, depending upon impurities. It has a characteristic luster and odor. It is black in color and melts at 90° to 100° C.

It is found in rocks of all ages, but there are only a few deposits of large extent. The most noted locality is on the island of Trinidad, where there is a lake of it 1½ miles in circumference, which is hot and liquid in the center, but grows cold and hard toward the edge. Large quantities are taken from this lake.

The principal use of asphalt is in making pavements for roads and walks. It is illustrated by two specimens:

(1) In trap rock. Hartford, Connecticut. (59934.)

(2) Massive. Island of Trinidad. (10678.)

Albertite is a variety of solid bitumen which is regarded as being dried and oxygenated petroleum of the following general composition:

	Per cent.
Carbon	86.04
Hydrogen	8.96
Oxygen	1.97
Nitrogen	2.93
Ash	0.10

It was formerly used for the distillation of oils for illuminating purposes, but since the discovery of petroleum it has ceased to be valuable for that purpose. It is illustrated by a single specimen :

(1) Albertite. New Brunswick, Canada. (59935.)

Uintite is a variety of bitumen having the following composition :

Specific gravity	1.062	1.065-1.07
	<i>Per cent.</i>	<i>Per cent.</i>
Carbon	80.88	78.43
Hydrogen	9.76	10.28
Nitrogen	3.30	2.27
Oxygen	6.05	8.70
Ash	0.01	0.40
	100.00	100.00
Analysis	Dr. T. M. Drown.	Fristoe & Lawver.

It is illustrated by a single specimen :

(1) Uintite. Uintah, Weber County, Utah. (59471.)

LIQUID BITUMEN.

PETROLEUM.

Composition: A mixture of various hydrocarbons of the marsh-gas and ethylene series and the paraffins.

It varies in specific gravity from 0.92 to 0.75. It is generally liquid, but hardens on exposure to the air, generally on account of oxidation, to semi-solid or even solid asphalt. It also thickens upon exposure to cold. Petroleum varies in color from black through many shades of brown, green, and red, to very light yellow.

The most generally accepted theory of the origin of petroleum is that it has resulted from the decomposition of animal and vegetable matter. It is found in rocks of all ages, from the oldest to the youngest, wherever circumstances have favored its collection and storage by natural agencies. It generally collects in an open, porous rock, sandstone or limestone, below an impervious cover of shale or slate. Small amounts of petroleum have been used for ages in medicine, particularly as a liniment. By far the largest amount is used for the preparation of illuminating oils, in which operation a considerable number of other valuable products are also formed. Where it is abundant and cheap it has also been used as a fuel.

Petroleum has been produced in large amounts in the United States

since 1860, and its occurrence is very fully illustrated by a large collection prepared by Prof. S. F. Peckham in connection with a report for the Tenth Census. A copy of this report will be found on the table in the exhibition hall and should be consulted in connection with the specimens. This collection is, in some cases, supplemented by specimens from other sources.

The Tenth Census collection was originally arranged and treated upon a geographical basis, but for Museum purposes several series have been selected from the geographical series to illustrate certain points.

The first series is arranged to show gradually decreasing specific gravity. The series begins with a very dark oil of 22° Baumé = 0.9210 specific gravity. In general as the specific gravity decreases the color grows lighter. To this, however, there are several notable exceptions. For instance, No. 59736 (32° Baumé = 0.8641 specific gravity) is much lighter than its associates. The same is also true of No. 59735 (45° Baumé = 0.8000 specific gravity) and No. 59743 (47° Baumé = 0.7909 specific gravity). On the other hand No. 59506 (48° Baumé = 0.7865 specific gravity) and 59591 ($48\frac{1}{2}^{\circ}$ Baumé = 0.7854 specific gravity) are darker than their associates, while the color of No. 59584, with the very low gravity of $50\frac{1}{2}^{\circ}$ Baumé = 0.7755 specific gravity, is as dark as any member of the series.

The best and almost the only way to get an idea of the specific gravity of the specimens, short of making a direct determination, is to tip the bottle on the side and observe the rate at which the film, that is formed on the glass when the bottle is returned to the perpendicular, flows back. In this respect the series shows a gradual change. The heavy oils take some time to flow back, while the lightest flows back almost instantly.

(1) 22° Baumé = 0.9210 specific gravity, dark greenish. Colorado. (59741.)

(2) $23\frac{1}{4}^{\circ}$ Baumé = 0.9120 specific gravity, black. From the Trenton limestone. J. W. Mitchell Well, Plum Lick Creek, near Middletown, Bourbon County, Kentucky. (59594.)

(3) 27° Baumé = 0.8917 specific gravity, black. From the millstone grit (Carboniferous). Lem Beck Well, near Volcano, Wood County, West Virginia. (59553.)

(4) $28\frac{1}{4}^{\circ}$ Baumé = 0.8833 specific gravity, black. From the millstone grit (Carboniferous), near Volcano, Wood County, West Virginia. (59555.)

(5) 29° Baumé = 0.8805 specific gravity, black. Brockin Well, Johnson County, Kentucky. (59597.)

(6) 30° Baumé = 0.8750 specific gravity, black. From the millstone grit (Carboniferous), near Volcano, Wood County, West Virginia. (59557.)

(7) $31\frac{1}{4}^{\circ}$ Baumé = 0.8668 specific gravity, dark greenish. Broward Well, Johnson County, Kentucky. (59598.)

(8) $32\frac{1}{4}^{\circ}$ Baumé = 0.8614 specific gravity, dark greenish red. Greensburgh, Westmoreland County, Pennsylvania. (59736.)

(9) 33° Baumé = 0.8588 specific gravity, black. From the Trenton limestone. Taskin Well, near North Baltimore, Wood County, Ohio. (59566.)

(10) 34° Baumé = 0.8536 specific gravity, black. Oil in sand, here 23 feet in thickness; depth of well 551 feet; drilled 1877; torpedoed; yielded 3 barrels of oil on first day of flow. Lot 4823, Howe, Forest County, Pennsylvania. (59505.)

(11) 35° Baumé = 0.8484 specific gravity, black. From the first sandstone of the Great Conglomerate (Upper Carboniferous). Well No. 6, West Virginia Oil and Oil Land Company, White Oak district, Ritchie County, West Virginia. (59857.)

(12) 36° Baumé = 0.8433 specific gravity, dark greenish. From the first sandstone of the Great Conglomerate (Upper Carboniferous). Oil in sand. Well No. 7, West Virginia Oil and Oil Land Company, White Oak district, Ritchie County, West Virginia. (59858.)

(13) 37° Baumé = 0.8383 specific gravity, black. Oil in limestone, here 50 feet in thickness; depth of well 1,321 feet; drilled 1885; torpedoed; yielded 50 barrels of oil on first day of flow. Brick Yard Well, Findlay, Hancock County, Ohio. (59807.)

(14) 38° Baumé = 0.8333 specific gravity, dark greenish. From the first sandstone of the Great Conglomerate (Upper Carboniferous). Oil in sand. West Virginia Oil and Oil Land Company, White Oak District, Ritchie County, West Virginia. (59860.)

(15) 39° Baumé = 0.8284 specific gravity, dark greenish red. From Clarion County sand; depth of well 860 feet; drilled 1883; torpedoed; yielded 2 barrels of oil on first day of pumping. Cumming's Well No. 1, Cumming's Farm, Tionesta, Forest County, Pennsylvania. (59816.)

(16) 40° Baumé = 0.8235 specific gravity, dark greenish. Bradford County, Pennsylvania. (59734.)

(17) 41° Baumé = 0.8187 specific gravity, dark greenish. Parker County, Pennsylvania. (59733.)

(18) 42° Baumé = 0.8139 specific gravity, dark greenish. From the third sandstone of the Petroleum Measures (Venango). Black Gas Well, Pleasantville, Venango County, Pennsylvania. (59580.)

(19) 43° Baumé = 0.8092 specific gravity, dark greenish red. Oil-bearing sand here 20 feet in thickness; depth of well 1,855 feet; drilled 1883; torpedoed; yielded 2,200 barrels of oil on first day of flow. Reno Well No. 1, Cooper tract, Sheffield, Warren County, Pennsylvania. (59765.)

(20) 44° Baumé = 0.8045 specific gravity, dark greenish. Bullion district, Warren County, Pennsylvania. (59737.)

(21) 44½° Baumé = 0.8023 specific gravity, dark greenish. From third sandstone of the Petroleum Measures (Venango). Sand here, 14 feet in thickness. Oil in sand; depth of well 708 feet; drilled 1868; torpedoed; yielded 330 barrels of oil on first day of flow. Well No. 6, Hamby Farm, Rockland, Venango County, Pennsylvania. (59788.)

(22) 45° Baumé = 0.8000 specific gravity, dark amber. Clarion County, Pennsylvania. (59735.)

(23) 45½° Baumé = 0.7977 specific gravity, dark greenish red. Thom Creek district, Butler County, Pennsylvania. (59746.)

(24) 46° Baumé = 0.7954 specific gravity, dark greenish. Foxburgh, Clarion County, Pennsylvania. (59739.)

(25) 46½° Baumé = 0.7932 specific gravity, black. Depth of well 660 feet; drilled, 1866; yielded 600 barrels oil first day of flow. Well No. 184, Burtess lease, Allegheny County, Pennsylvania. (59769.)

(26) 46¾° Baumé = 0.7921 specific gravity, black. From the third sandstone of the Petroleum Measures (Venango). Titusville, Venango County, Pennsylvania. (59507.)

(27) 47° Baumé = 0.7909 specific gravity, dark amber. Smith's Ferry, Allegheny County, Pennsylvania. (59743.)

(28) 47½° Baumé = 0.7887 specific gravity, dark greenish red. From the first sandstone of the Petroleum Measures (Venango). Beck Well, near Pleasantville, Venango County, Pennsylvania. (59583.)

(29) 47¾° Baumé = 0.7876 specific gravity, dark greenish red. From the fourth sandstone of the Petroleum Measures; oil in sand; depth of well 14 feet; drilled 1871; torpedoed; yielded 900 barrels of oil on first day of flow. Well No. 1, farm of J. Blaney, Fairview, Butler County, Pennsylvania. (59799.)

(30) 48° Baumé = 0.7865 specific gravity, black. Webb Oil Company, Taskill, Venango County, Pennsylvania. (59506.)

(31) 48½° Baumé = 0.7843 specific gravity, dark greenish. From the third sandstone of the Petroleum Measures (Venango). Cogley Field, Ashley, Clarion County, Pennsylvania. (59591.)

(32) 48½° Baumé = 0.7832 specific gravity, dark amber. Oil in sand, here 16 feet in thickness; depth of well 1,025 feet; drilled 1878; torpedoed; yielded 20 barrels of oil on first day of flow. Well No. 1, Lot No. 55, Mead, Warren County, Pennsylvania. (59780.)

(33) 49° Baumé = 0.7821 specific gravity, light greenish red. Oil in sand; depth of well 1,254 feet. Tiona Oil Company, Warren County, Pennsylvania. (59514.)

(34) 50° Baumé = 0.7777 specific gravity, light greenish red. Oil in sand, here 50 feet in thickness. Cameron Well, Smith Pool, Washington County, Pennsylvania. (59589.)

(35) 50½° Baumé = 0.7755 specific gravity, black. Haskell Well, Wigglesworth Tract, Venango County, Pennsylvania. (59584.)

(36) 51° Baumé = 0.7734 specific gravity, light greenish yellow. Oil in sand here 50 feet in thickness. Nicholas Well, Vanceville, Washington County, Pennsylvania. (59600.)

(37) 54° Baumé = 0.7608 specific gravity, dark amber. Oil in sand; depth of well 2,113 feet; drilled 1885; torpedoed; yielded 15 barrels of oil on first day of flow. Gantz Well No. 1, Little Washington, Washington County, Pennsylvania. (59777.)

The following series of twelve specimens illustrates the principle variations in color. The series may be divided into two portions, beginning with a thoroughly black specimen and following through increasing amounts of green and red to a light greenish yellow in the first portion, and in the second beginning with a dark red and following through to a light straw, in which the greenish element of the color does not appear.

(1) Black. Bear Creek, Burkesville, Cumberland County, Kentucky. (59832.)

(2) Black, tinged with green. Mecca, Trumbull County, Ohio. (59757.)

(3) Dark greenish. Anchor Well No. 3, Glade, Warren County, Pennsylvania. (59761.)

(4) Dark greenish red. Dale Brothers' Well No. 1, Batten Farm, near Rockland, Venango County, Pennsylvania. (59767.)

(5) Dark greenish red. Kane, Armstrong County, Pennsylvania. (59752.)

(6) Light greenish red. Gordon Well, Washington, Washington County, Pennsylvania. (59526.)

(7) Greenish yellow. Leedecker Well, Butler County, Pennsylvania. (59750.)

(8) Dark red. New Brinker Well, Pleasant Valley, Westmoreland County, Pennsylvania. (59520.)

(9) Light red. Galtz Well, Washington, Washington County, Pennsylvania. (59527.)

(10) Amber. Hess, Sackett & Eichner Well No. 1, Reidsburgh, Clarion County, Pennsylvania. (59581.)

(11) Yellow. Riggs Gas Well, Moundsville, Marshall County, West Virginia. (59579.)

(12) Light straw. Farm of J. Somerville, near Brady's Bend, Armstrong County, Pennsylvania. (59494.)

The following series shows the occurrence in different geological formations arranged in a generally descending order. There is a certain

amount of overlapping, however, between the West Virginia and Pennsylvania series, since the oil-bearing strata in these two States have not been correlated.

The West Virginia and Pennsylvania series have been arranged according to the generalized sections given by Professor Peckham in PL. VIII, facing page 46, and PL. V, facing page 50 of the Tenth Census report:

(1) From the Tertiary sandstone. Dark greenish. Pico district, Los Angeles County, California. (59552.)

(2) From the Tertiary sandstone. Black; specific gravity 23.5° Baumé. Oil Springs, Nacogdoches, Nacogdoches County, Texas. (59571.)

(3) From the Cretaceous formation. Dark greenish. Cañon City, Fremont County, Colorado. (59548.)

The following eighteen specimens are from the West Virginia oil field. Their location in depth is referred to the Crinoidal limestone as a datum line.

(1) 50 feet above the Crinoidal limestone. Black; specific gravity 28° Baumé. Oil in sand; depth of well 56 feet; drilled 1859; not torpedoed; yielded 100 barrels of oil on first day of pumping. Well No. 1, Dutton farm, Aurelius, Washington County, Ohio. (59855.)

(2) 100 feet below the Crinoidal limestone. Dark greenish. Oil in sand; depth of well 150 feet; drilled 1882; torpedoed; yielded 10 barrels of oil on first day of pumping. Farm of Frank Atkinson, Aurelius, Washington County, Ohio. (59854.)

(3) 200 feet below the Crinoidal limestone. Black. Oil in sand; depth of well 160 feet; not torpedoed. Rathbone oil tract, Burning Springs district, Wirt County, West Virginia. (59837.)

(4) 250 feet below the Crinoidal limestone. Dark greenish. Oil in sand; depth of well 350 feet. Well No. 6, farm of George Rice, Aurelius, Washington County, Ohio. (59853.)

(5) 300 feet below the Crinoidal limestone. Black. Oil in sand; depth of well 275 feet. Rathbone oil tract, Burning Springs district, Wirt County, West Virginia. (59838.)

(6) 450 feet below the Crinoidal limestone. Dark greenish. Oil in sand; depth of well 500 feet; drilled 1865; torpedoed; yielded 8 barrels of oil on first day of pumping. Well No. 1, farm of George Rice, Aurelius, Washington County, Ohio. (59852.)

(7) 650 feet below the Crinoidal limestone. Black. Oil in sand; depth of well 800 feet; not torpedoed; yielded 5 barrels of oil on first day of pumping. Newton Farm, Aurelius, Washington County, Ohio. (59850.)

(8) 820 feet below the Crinoidal limestone. Black. Oil in sand; depth of well 840 feet. Petty Farm, Burning Springs district, Wirt County, West Virginia. (59839.)

(9) 930 feet below the Crinoidal limestone. Dark greenish; specific gravity 28° Baumé. Oil in sand; depth of well 400 feet. Volcanic Coal and Oil Company, White Oak district, Ritchie County, West Virginia. (59844.)

(10) 950 feet below the Crinoidal limestone. Black; specific gravity 29° Baumé. Oil in sand; depth of well 450 feet. West Virginia Oil and Oil Land Company, White Oak district, Ritchie County, West Virginia. (59842.)

(11) 950 feet below the Crinoidal limestone. Dark greenish; specific gravity 40° Baumé. Oil in sand; depth of well 400 feet. West Virginia Oil and Oil Land Company, White Oak district, Ritchie County, West Virginia. (59848.)

(12) 960 feet below the Crinoidal limestone. Dark greenish; specific gravity 33° Baumé. Oil in sand; depth of well 380 feet. Volcanic Oil and Coal Company, White Oak district, Ritchie County, West Virginia. (59847.)

(13) 980 feet below the Crinoidal limestone. Dark greenish; specific gravity 30° Baumé. Oil in sand; depth of well 400 feet. Volcanic Oil and Coal Company, White Oak district, Ritchie County, West Virginia. (59943.)

(14) 980 feet below the Crinoidal limestone. Dark greenish; specific gravity 31° Baumé. Oil in sand; depth of well 400 feet. Volcanic Oil and Coal Company, White Oak district, Ritchie County, West Virginia. (59845.)

(15) 1,100 feet below the Crinoidal limestone. Dark greenish; specific gravity 47° Baumé. Oil in sand; depth of well 1,100 feet. Gracy Lease, Burning Springs district, Wirt County, West Virginia. (59840.)

(16) 1,100 feet below the Crinoidal limestone. Black; specific gravity 27° Baumé. Oil in sand; depth of well 650 feet; drilled 1881. Well No. 1, Volcanic Oil and Coal Company, Sand Hill district, Wood County, West Virginia. (59841.)

(17) 1,350 feet below the Crinoidal limestone. Amber; specific gravity 39° Baumé. Oil in sand; depth of well 1,350 feet; drilled 1880; torpedoed; yielded 18 barrels of oil on first day of flow. Well No. 14, farm of George Rice, Aurelius, Washington County, Ohio. (59851.)

(18) 1,500 feet below the Crinoidal limestone. Dark greenish; specific gravity 50° Baumé. Oil in sand; depth of well 1,000 feet. Gale tract, White Oak district, Ritchie County, West Virginia. (59849.)

The following twenty-eight specimens illustrate the occurrence at different depths in the Pennsylvania field:

(1) 180 feet below the Pittsburgh coal bed. Light greenish red; specific gravity 34° Baumé. Bailey farm, Dunkard Creek, Greene County, Pennsylvania. (59536.)

(2) 460 feet below the Pittsburgh coal bed. Greenish red; specific gravity 35° Baumé. Maple Well, Dunkard, Greene County, Pennsylvania. (59577.)

(3) 480 feet below the Pittsburgh coal bed. Dark greenish red; specific gravity 35° Baumé. Garrison Well, Dunkard, Greene County, Pennsylvania. (59578.)

(4) 650 feet below the Pittsburgh coal bed. Drilled in 1885, and only a few gallons of oil were obtained; light greenish red. Clark's farm, Washington County, Pennsylvania. (59523.)

(5) "Mountain Sand" of the Petroleum Measures (Lower Carboniferous). Dark greenish red. Manifold Well No. 1, Washington County, Pennsylvania. (59519.)

(6) 1,400 feet below the Pittsburgh coal bed. Light greenish red. Huskill Well, Mount Morris, Greene County, Pennsylvania. (59534.)

(7) From the first sandstone of the Petroleum Measures (Venango). Total yield of well 25 barrels of oil; dark greenish; specific gravity 41° Baumé. McKeesport, Allegheny County, Pennsylvania. (59582.)

(8) From the first sandstone of the Petroleum Measures (Venango). Sand here 16 feet in thickness; oil in sand; depth of well 337 feet; drilled 1870; torpedoed; yielded 225 barrels of oil on first day of pumping; black; specific gravity 32° Baumé. Well No. 1, farm of J. Blakely, Sugar Creek, Venango County, Pennsylvania. (59781.)

(9) From the second sandstone of the Petroleum Measures (Venango). Sand here 38 feet in thickness; oil in sand; depth of well 583 feet; drilled 1872; torpedoed; yielded 2 barrels of oil on first day of pumping; black; specific gravity 43° Baumé. Well No. 3, farm of Jennings & Ralston, Jackson, Venango County, Pennsylvania. (59774.)

(10) From the second sandstone of the Petroleum Measures (Venango). Dark greenish; specific gravity 47° Baumé. Haskell Well, Allegheny, Venango County, Pennsylvania. (59585.)

(11) From the second sandstone of the Petroleum Measures (Venango). Sand here 50 feet in thickness; oil in sand; depth of well 855 feet; drilled 1862; torpedoed; yielded 1½ barrels of oil on first day of pumping. Dark greenish; specific gravity 42° Baumé. Cumming's Well, Holliday Run farm, Oil City, Venango County, Pennsylvania. (59813.)

(12) From the second sandstone of the Petroleum Measures (Venango). Sand here 20 feet in thickness; oil in sand; depth of well 1,875 feet; drilled 1883; torpedoed; yielded 550 barrels of oil on first day of flow. Dark greenish red; specific gravity on sample collected August, 1885, $40\frac{1}{2}^{\circ}$ Baumé. Anchor Well No. 3, Cooper tract, Sheffield, Warren County, Pennsylvania. (59763.)

(13) From the gray sandstone of the Petroleum Measures (Venango.) Dark greenish. Fisher Well No. 3, Gates, Venango County, Pennsylvania. (59904.)

(14) From just above the third sandstone of the Petroleum Measures (Venango). Sand here 22 feet in thickness; oil in sand; depth of well 1,076 feet; drilled 1885; torpedoed; yielded 18 barrels of oil on first day of pumping. Dark greenish; specific gravity 49° Baumé. Well No. 5, Diamond farm, Cranberry, Venango County, Pennsylvania. (59795.)

(15) From the third sandstone of the Petroleum Measures (Venango). Sand 18 feet in thickness; oil in sand; depth of well 957 feet; drilled 1885; not torpedoed; yielded 35 barrels of oil on first day of pumping. Black; specific gravity $48\frac{1}{2}^{\circ}$ Baumé. Well No. 1, Heckerthorne farm, Cranberry, Venango County, Pennsylvania. (59815.)

(16) From third sandstone of the Petroleum Measures (Venango). Black; specific gravity 48° Baumé. Sackett & Eichner Well No. 4, Taskell Field, Cranberry, Venango County, Pennsylvania. (59587.)

(17) From the third sandstone of the Petroleum Measures (Venango). Sand here 25 feet in thickness; oil in sand; depth of well 490 feet; drilled 1864; torpedoed; yielded 600 barrels of oil on first day of flow. Dark greenish; specific gravity on sample collected August, 1885, $39\frac{1}{2}^{\circ}$ Baumé. Hammond Well No. 1, farm of John Steele or "Coal Oil Johnny," Cherry Tree, Venango County, Pennsylvania. (59790.)

(18) From the third sandstone of the Petroleum Measures. Sand here 13 feet in thickness; oil in sand; depth of well 1,180 feet; drilled 1875; torpedoed; yielded 45 barrels of oil on first day of pumping. Greenish brown; specific gravity on sample collected September, 1885, $47\frac{1}{2}^{\circ}$ Baumé. Well No. 1, Fletcher Farm, Parker, Butler County, Pennsylvania. (59798.)

(19) This was the first well drilled for oil, and oil was found at the depth of $69\frac{1}{2}$ feet in one of the "mountain sands;" afterwards deepened to the third sandstone of the Petroleum Measures (Venango). Depth of well 500 feet; drilled 1859; not torpedoed; yielded 10 barrels of oil on first day of flow; afterwards yielded 40 barrels on first day of pumping. Dark greenish; specific gravity on sample collected March, 1885, $40\frac{1}{2}^{\circ}$ Baumé. Drake Well, Pennsylvania Rock Oil Company, Cherry Tree, Venango County, Pennsylvania. (59768.)

(20) From third sandstone of the Petroleum Measures (Venango). Sand here 35 feet in thickness; oil in sand; depth of well 1,685 feet; drilled 1885; torpedoed; yielded 7,000 barrels of oil on first day of flow. This well was unproductive until torpedoed. After shot was fired, and before the well could be brought under control it was estimated that from 12,000 to 19,000 barrels of oil were produced in the first 24 hours. Dark greenish red; specific gravity 48° Baumé. Well No. 1, Marshal, Penn, Butler County, Pennsylvania. (59782.)

(21) From third sandstone of the Petroleum Measures. Sand here 60 feet in thickness; oil in sand; depth of well 950 feet; drilled 1872; not torpedoed; yielded 50 barrels of oil on first day of flow. Dark red; specific gravity on sample collected in 1873, $51\frac{1}{2}^{\circ}$ Baumé. Ross Farm, Dunkard, Greene County, Pennsylvania. (59792.)

(22) From the third sandstone of the Petroleum Measures. Sand here 22 feet in thickness; oil in sand; depth of well 917 feet; drilled 1884; torpedoed; yielded 400 barrels of oil on first day of flow. Dark amber; specific gravity on sample collected October, 1885, 47° Baumé. Well No. 1, Rodgers Tract, Glade, Warren County, Pennsylvania. (59803.)

(23) From the fourth sandstone of the Petroleum Measures. Dark greenish red; specific gravity $44\frac{1}{2}^{\circ}$ Baumé. Kangaroo Well No. 1, East Brady, Clarion County, Pennsylvania. (59489.)

(24) From the fourth sandstone of the Petroleum Measures. Dark greenish red. Well No. 34, Brady's Bend Iron Company's Tract, Armstrong County, Pennsylvania. (59490.)

(25) From the third Bradford sand. Black. Nile Oil Company, Wert, Allegany County, New York. (59477.)

(26) From the third Bradford sand. Dark greenish. Scott & Smith's Well No. 1, Bolivar, Allegany County, New York. (59478.)

(27) From the third Bradford sand. Dark greenish; specific gravity $42\frac{1}{2}^{\circ}$ Baumé. Forrest Oil Company, Bradford, McKean County, Pennsylvania. (59480.)

(28) From the third Bradford sand. Greenish red. Kane Oil Company's Well, Wetmore, McKean County, Pennsylvania. (59482.)

The following nine specimens from various localities continue the section to the lowest point at which petroleum has been found:

(1) From the Middle Devonian formation. Black. Near Glasgow, Barren County, Kentucky. (59544.)

(2) From the corniferous limestone. Black; specific gravity 35.5° Baumé. Crown Well, Enniskillen, province of Ontario, Canada. (59569.)

(3) From the corniferous limestone. Black; specific gravity 32° Baumé. Crown Well, Enniskillen, province of Ontario, Canada. (59568.)

(4) From the upper Hudson River shales (Lower Silurian). Dark greenish; specific gravity 43.5° Baumé. Well No. 2, near Glasgow, Barren County, Kentucky. (59569.)

(5) From the Hudson River shales. Black; specific gravity 37.5° Baumé. Crocus Well, near Burkesville, Cumberland County, Kentucky. (59570.)

(6) From the Hudson River group (Lower Silurian). Black; specific gravity 32° Baumé. Pioneer Well, Francisville, Pulaski County, Indiana. (59575.)

(7) From the Trenton limestone. Black. Farm of Whitacre, Liberty, Wood County, Ohio. (59601.)

(8) From the Trenton limestone. Black. Test well. Lima, Allen County, Ohio. (59551.)

(9) From the Trenton limestone. Black; specific gravity 33.5° Baumé. Brightwood, Marion County, Indiana. (59574.)

The balance of the petroleum collection is arranged on a geographical basis.

(1) Dark greenish. From the third Bradford sand. Cooper Brothers' well No. 1, Genesee, Allegany County, New York. (59473.)

(2) Dark greenish. From the third Bradford sand. Allen & Co.'s well, Alma, Allegany County, New York. (59474.)

(3) Dark greenish. From the third Bradford sand. Willett's well No. 1, Genesee, Allegany County, New York. (59475.)

(4) Black. From the third Bradford sand. Boyle Well, Wirt Centre, Allegany County, New York. (59476.)

(5) Dark greenish red, specific gravity 46° Baumé. From the third sandstone of the Petroleum Measures; sand here 35 feet in thickness; oil in sand; depth of well 925 feet; drilled 1893; torpedoed. Well No. 7, lot No. 41, Richburgh, Allegany County, New York. (59786.)

(6) Dark greenish. From the third Bradford sand. Johnson Farm, Four-Mile Run, Cattaraugus County, New York. (59479.)

(7) Dark greenish. Cattaraugus County, New York. (59723.)

(8) Dark greenish. From the third Bradford sand. P. Newell Well, near Bradford, McKean County, Pennsylvania. (59481.)

(9) Dark greenish. W. Chambers Well, Kendall Creek, McKean County, Pennsylvania. (48483.)

(10) Dark greenish. From the third Bradford sand. Association Well, McKean County, Pennsylvania. (59484.)

(11) Dark greenish. McKean County, Pennsylvania. (59725.)

(12) Dark greenish, specific gravity on sample collected March, 1885, 46° Baumé. Oil in sand, here 45 feet in thickness; depth of well 1,405 feet; drilled 1882; torpedoed; yielded 100 barrels of oil on first day of flow. Well No. 5, F. W. Mitchell's Lease, Duke Centre, McKean County, Pennsylvania. (59773.)

(13) Dark greenish, specific gravity 48° Baumé. Oil in sand; depth of well 2,337 feet. Well No. 1, Lot 3767, Wetmore, McKean County, Pennsylvania. (59809.)

(14) Dark greenish red. Oil in sand; depth of well about 1,000 feet; drilled 1882; torpedoed; yielded 20 barrels of oil on first day of flow. Farm of Silas Richardson, Congdon, McKean County, Pennsylvania. (59823.)

(15) Dark greenish red. Weed Farm, Kinzua, Warren County, Pennsylvania. (59513.)

(16) Light greenish red. Moore & Co.'s well No. 1, Mead, Warren County, Pennsylvania. (59515.)

(17) Dark greenish, specific gravity 48° Baumé. Well No. 646, Warren County, Pennsylvania. (59740.)

(18) Dark greenish red, specific gravity on sample collected August, 1885, 45° Baumé. Oil-bearing sand here 70 feet in thickness; depth of well 780 feet; drilled 1877; torpedoed; yielded 10 barrels of oil on first day of pumping. Well No. 1, farm of E. M. Lacy, Glade, Warren County, Pennsylvania. (59759.)

(19) Dark greenish red, specific gravity on sample collected August, 1885, 48° Baumé. Oil-bearing sand here 20 feet in thickness; depth of well 1,630 feet; drilled 1882; torpedoed. This is the famous "Mystery Well" that caused a decline in the market to 50 cents per barrel. Yielded 2,500 barrels on first day of flow. Grace or "Mystery Well" Cherry Grove, Warren County, Pennsylvania. (59762.)

(20) Black, specific gravity 49° Baumé. Oil-bearing sand here 15 feet in thickness; depth of well 1,050 feet; drilled 1885; not torpedoed; yielded 15 barrels of oil on first day of pumping. Economites Well No. 1, lot 5204, Limestone, Warren County, Pennsylvania. (59764.)

(21) Dark greenish, specific gravity on sample collected September, 1885, 45° Baumé. From the third sandstone of the Petroleum Measures; sand here 18 feet in thickness; oil in sand; depth of well 690 feet; drilled 1865; torpedoed; yielded 450 barrels of oil on first day of flow. Well No. 9, Economite Farm, Limestone, Warren County, Pennsylvania. (59800.)

(22) Dark greenish, specific gravity on sample collected September, 1885, 47° Baumé. From the third sandstone of the Petroleum Measures; sand here 22 feet in thickness; oil in sand; depth of well 1,750 feet; drilled 1882; torpedoed; yielded 650 barrels of oil on first day of flow. Lot 672, Cherry Grove, Warren County, Pennsylvania. (59801.)

(23) Dark greenish, specific gravity 43° Baumé. Oil in sand, here 42 feet in thickness; depth of well 1,542 feet; drilled 1885; torpedoed; yielded 3 barrels of oil on first day of flow. Well No. 1, lot 754, Cherry Grove, Warren County, Pennsylvania. (59810.)

(24) Dark greenish red. Wardwell farm, Warren County, Pennsylvania. (59821.)

(25) Dark greenish red. Wardwell pool, Warren County, Pennsylvania. (59822.)

(26) Dark greenish red. From the third sandstone of the Petroleum Measures, here 40 feet in thickness; oil in sand; depth of well 850 feet; drilled, 1883; torpedoed; yielded 200 barrels of oil on first day of flow. Farm of J. M. Wardwell, Mead, Warren County, Pennsylvania. (59824.)

(27) Dark greenish red. Oil in sand; depth of well about 1,000 feet; drilled, 1884; torpedoed; yielded 500 barrels of oil on first day of flow. McWilliam farm, Glade, Warren County, Pennsylvania. (59825.)

(28) Dark greenish red. Oil in sand, here 40 feet in thickness; depth of well

550 feet; drilled 1884; torpedoed; yielded 40 barrels of oil on first day of flow. Farm of J. M. Wardwell, Mead, Warren County, Pennsylvania. (59826.)

(29) Dark greenish, specific gravity 45.25° Baumé. From the third sandstone of the Petroleum Measures; oil in sand, here 23 feet in thickness; depth of well 602 feet; drilled 1868; torpedoed; yielded 50 barrels of oil on first day of pumping. Well No. 7, Economy Oil Company, Tidioute, Warren County, Pennsylvania. (59829.)

(30) Dark greenish, specific gravity 26° Baumé. Oil in slate; depth of well 600 feet; drilled, 1841. Demming's well, Erie, Erie County, Pennsylvania. (59820.)

(31) Dark greenish. Crawford County, Pennsylvania. (59730.)

(32) Dark greenish. Octave Oil Company, near Titusville, Crawford County, Pennsylvania. (59819.)

(33) Dark greenish red. Well No. 1, Reno Oil Company, Forest County, Pennsylvania. (59516.)

(34) Dark greenish red. Well No. 5, Graham & Co., Howe, Forest County, Pennsylvania. (59517.)

(35) Dark greenish red, specific gravity on sample collected June, 1885, 47.50° Baumé. From the third sandstone of the Petroleum Measures; sand here 15 feet in thickness; oil in sand; depth of well 1,655 feet; drilled 1883; torpedoed; yielded 1,950 barrels of oil on first day of flow. Well No. 12, lot 3194, Howe, Forest County, Pennsylvania. (59789.)

(36) Dark greenish red, specific gravity on sample collected October, 1885, 46.50° Baumé. From the third sandstone of the Petroleum Measures; sand here 23 feet in thickness; oil in sand; depth of well 1,158 feet; drilled, 1885; not torpedoed; yielded 75 barrels of oil on first day of flow. Well No. 1, Chrisman farm, Howe, Forest County, Pennsylvania. (59804.)

(37) Dark greenish red. Hughes & Co.'s well, Elk County, Pennsylvania. (59522.)

(38) Dark greenish. From the third sandstone of the Petroleum Measures (Venango). Dale well No. 5, Jolly farm, Venango County, Pennsylvania. (59505.)

(39) Dark greenish. Taylor well, Bullion Oil Company, McCalmont farm, Venango County, Pennsylvania. (59508.)

(40) Dark greenish. From the second sandstone of the Petroleum Measures (Venango). Ress well No. 3, Gormley farm, Venango County, Pennsylvania. (59509.)

(41) Dark greenish. Story farm, Oil Creek, Venango County, Pennsylvania. (59510.)

(42) Black. Oil Creek, Venango County, Pennsylvania. (59511.)

(43) Black. Blood farm, Oil Creek, Venango County, Pennsylvania. (59512.)

(44) Black, specific gravity 28.5° Baumé. From the first sandstone of the Petroleum Measures (Venango). Allen and Era well, Franklin, Venango County, Pennsylvania. (59592.)

(45) Dark green. Franklin district, Venango County, Pennsylvania. (59722.)

(46) Dark greenish. Bullion district, Venango County, Pennsylvania. (59726.)

(47) Dark greenish, specific gravity 34.5° Baumé. Franklin, Venango County, Pennsylvania. (59745.)

(48) Dark greenish red, specific gravity 46° Baumé; surface oil. Rockland, Venango County, Pennsylvania. (59755.)

(49) Dark greenish, specific gravity on sample collected July, 1885, 45° Baumé. From the third sandstone of the Petroleum Measures, here 22 feet in thickness; oil in sand; depth of well 465 feet; drilled 1860; torpedoed; yielded 25 barrels of oil on first day of flow, afterwards yielding 25 barrels of oil on first day of pumping. This was the third well drilled for oil, and is still producing (1885) 5 barrels of oil per day. Crosby well No. 1, Octave Oil Company, Oil Creek, Venango County, Pennsylvania. (59766.)

(50) Black, specific gravity, 45° Baumé. Oil in sand, here 16 feet in thickness; depth of well 870 feet; drilled, 1868; torpedoed; yielded 80 barrels of oil on first day of pumping. Well No. 2, Armstrong farm, Oil Creek, Venango County, Pennsylvania. (59770.)

(51) Dark greenish, specific gravity 42.50° Baumé. Oil in sand, here 29 feet in thickness; depth of well 1,084 feet; drilled 1885; torpedoed; yielded 24 barrels of oil on the first day of pumping. Well No. 1, Young's farm, Rockland, Venango County, Pennsylvania. (59772.)

(52) Dark greenish, specific gravity 45° Baumé. From the third sandstone of the Petroleum Measures (Venango); sand here 28 feet in thickness; oil in sand; depth of well 606 feet; drilled 1871; torpedoed; yielded 8 barrels of oil on first day of pumping. Well No. 2, farm of Jennings & Ralston, Jackson, Venango County, Pennsylvania. (59775.)

(53) Dark greenish, specific gravity in 1867, 48° Baumé, in 1885, 47° Baumé. Oil in sand, here 57 feet in thickness; depth of well 835 feet; drilled 1867; yielded 210 barrels of oil on first day of pumping. Well No. 127, Cherry Run Oil Company, Oil Creek, Venango County, Pennsylvania. (59776.)

(54) Dark greenish, specific gravity 44° Baumé. Oil in sand, here 12 feet in thickness; depth of well 780 feet; drilled 1883; torpedoed; yielded 50 barrels of oil on first day of pumping. Emlenton, Venango County, Pennsylvania. (59778.)

(55) Dark greenish, specific gravity in 1877, 46° Baumé. Oil in sand, here 31 feet in thickness; depth of well 836 feet; drilled 1877; torpedoed; yielded 3,600 barrels of oil on first day of flow. Big Injun well, Simcox farm, Clinton, Venango County, Pennsylvania. (59784.)

(56) Dark greenish, specific gravity in 1868, 48° Baumé, in 1885, 47° Baumé. Oil in sand, here 17 feet in thickness; depth of well 862 feet; drilled 1868; torpedoed; yielded 35 barrels of oil on first day of pumping. Well No. 1, Nettleton farm, Oil Creek, Venango County, Pennsylvania. (59785.)

(57) Black, specific gravity in 1868, 40° Baumé, in 1885, 37½ Baumé. From the second sandstone of the Petroleum Measures; sand here 30 feet in thickness; oil in sand; depth of well 622 feet; torpedoed; yielded 25 barrels of oil on first day of pumping. Well No. 2, Philadelphia and Boston farm, Rockland, Venango County, Pennsylvania. (59787.)

(58) Dark greenish, specific gravity on sample collected September, 1885, 43.50° Baumé. From the third sandstone of the Petroleum Measures (Venango); sand here 31 feet in thickness; oil in sand; depth of well 956 feet; drilled 1871; yielded 250 barrels of oil on first day of flow. Hefferman & McDonald well, Milton farm, Bradensburg, Venango County, Pennsylvania. (56796.)

(59) Black, specific gravity 44° Baumé. From the first sandstone of the Petroleum Measures; sand here 51 feet in thickness; oil in sand; depth of well 775 feet; drilled 1885; torpedoed; yielded 17 barrels of oil on first day of pumping. Well No. 6, Norton tract, Oakland, Venango County, Pennsylvania. (59806.)

(60) Dark greenish red, specific gravity 48.50° Baumé. Oil in sand, here 80 feet in thickness; depth of well 325 feet; drilled 1885; not torpedoed; yielded 40 barrels of oil on first day of flow. This sample is especially interesting on account of its being found in the so-called "mountain sand," which lies above the first sandstone of the Petroleum Measures (Venango), and was never before known to produce oil. Well No. 1, Hertzell farm, Rockland, Venango County, Pennsylvania. (59811.)

(61) Dark greenish, specific gravity 43.50° Baumé. From the third sandstone of the Petroleum Measures (Venango); sand here 12 feet in thickness; oil in sand; depth of well 855 feet; drilled 1868; torpedoed; yielded 3 barrels of oil on first day of flow. Holiday Run farm, Oil City, Venango County, Pennsylvania. (59812.)

(62) Very dark red, specific gravity 49° Baumé. From the first sandstone of the Petroleum Measures (Venango); sand here 65 feet in thickness; oil in sand; depth of well 455 feet; drilled 1885; torpedoed; yielded 10 barrels of oil on first day of pumping. This well produces about 200 barrels of water with the oil per day; water flowed from the same sand as the oil. Davis well No. 2, Davis farm, Rockland, Venango County, Pennsylvania. (59814.)

(63) Dark greenish, specific gravity 49° Baumé. From the third sandstone of the Petroleum Measures (Venango); sand here 18 feet in thickness; oil in sand; depth of

well 1,000 feet; drilled 1882; torpedoed; yielded 506 barrels on first day of flow. Well No. 1, Sayer's farm, Egypt, Venango County, Pennsylvania. (59317.)

(64) Dark greenish red, specific gravity 48° Baumé. From the first and fourth sandstone of the Petroleum Measures (Venango). Piper & Brown well No. —, Clarion Field, Clarion, Clarion County, Pennsylvania. (59588.)

(65) Dark greenish, specific gravity $50\frac{1}{2}^{\circ}$ Baumé. From the Clarion County sandstone of the Petroleum Measures; sand here 15 feet in thickness; oil in sand; depth of well 1,020 feet; drilled 1885; torpedoed; yielded 80 barrels of oil on first day of pumping. Wood's Well No. 1, Young's farm, Ashland, Clarion County, Pennsylvania. (59758.)

(66) Dark greenish, specific gravity $45\frac{1}{2}^{\circ}$ Baumé. From the third sandstone of the Petroleum Measures; sand here 21 feet in thickness; oil in sand; depth of well 916 feet; drilled 1870; torpedoed; yielded 25 barrels of oil on first day of flow. Well No. 1, Fowler farm, Perry, Clarion County, Pennsylvania. (59797.)

(67) Light greenish red. Lawrence County, Pennsylvania. (59724.)

(68) Dark greenish red. From the third sandstone of the Petroleum Measures. Delap Well, No. 1, Petrolia, Butler County, Pennsylvania. (59495.)

(69) Dark greenish red. Warden Well No. 1, Butler County, Pennsylvania. (59496.)

(70) Dark greenish red. From the third sandstone of the Petroleum Measures. Well No. 19, Fisher Oil Company, Marshall farm, Butler County, Pennsylvania. (59497.)

(71) Light greenish red. From the second sandstone of the Petroleum Measures. Well No. 2, Uniontown Oil Company, Renfrew, Butler County, Pennsylvania. (59498.)

(72) Dark greenish. From the second sandstone of the Petroleum Measures. Maxwell & Middleton Well No. 1, Crawford Corners, Butler County, Pennsylvania. (59499.)

(73) Dark greenish red. From the fourth sandstone of the Petroleum Measures. Oil in sand; depth of well 1,462 feet. Forest Oil Company, Renfrew, Butler County, Pennsylvania. (59500.)

(74) Dark greenish red. Oil in sand, here 30 feet in thickness. Song Bird Well, Turner farm, Butler County, Pennsylvania. (59501.)

(75) Dark greenish. From the Boulder sand of the Petroleum Measures. Conley & Co.'s Well, Kelly farm, Butler County, Pennsylvania. (59502.)

(76) Dark greenish. Butler County, Pennsylvania. (59727.)

(77) Light greenish red. Russ & Sutton Well No. 3, Sugar Creek, Armstrong County, Pennsylvania. (59491.)

(78) Dark greenish red. From the fourth sandstone of the Petroleum Measures. Emma Jane Well No. 1, Armstrong Run, Armstrong County, Pennsylvania. (59492.)

(79) Dark greenish red. From the fourth sandstone of the Petroleum Measures. Davis & Evans Well No. 1, Brady's Bend Iron Company's tract, Brady's Bend, Armstrong County, Pennsylvania. (59493.)

(80) Dark greenish. Armstrong County, Pennsylvania. (59729.)

(81) Dark greenish red, specific gravity $45\frac{1}{2}^{\circ}$ Baumé. From the third sandstone of the Petroleum Measures; sand here 47 feet in thickness; oil in sand; depth of well 1,685 feet; drilled 1885; not torpedoed; yielded 200 barrels of oil on first day of flow. Ort Well No. 1, Ort farm, Sugar Creek, Armstrong County, Pennsylvania. (59791.)

(82) Dark greenish red. Well No. 1, Brady's Bend Iron Works, Armstrong County, Pennsylvania. (59827.)

(83) Amber. Old Well, Smith's Ferry, Beaver County, Pennsylvania. (59485.)

(84) Greenish yellow. Sample Well No. 4, Calhoun farm, Smith Ferry, Beaver County, Pennsylvania. (59486.)

(85) Dark greenish. 1,790 feet below the Pittsburgh Coal Bed. Marks Well, Racon Oil Company, Shousetounfield, Beaver County, Pennsylvania. (59487.)

(86) Dark greenish. Rochester, Beaver County, Pennsylvania. (59488.)

(87) Dark amber. Beaver County, Pennsylvania. (59732.)

(88) Dark amber, specific gravity on sample collected May, 1885, 47° Baumé. Oil in sand, here 15 feet in thickness; depth of well 925 feet; drilled 1874; yielded 60 barrels of oil on first day of pumping. Smith's Ferry district, South Beaver, Beaver County, Pennsylvania. (59779.)

(89) Very dark red, specific gravity 48° Baumé. Oil in sand, here 18 feet in thickness; depth of well 850 feet; drilled 1885; torpedoed; yielded 8 barrels of oil on first day of flow. Well No. 1, lease of Galey & Duffy, Moon, Beaver County, Pennsylvania. (59793.)

(90) Dark greenish red. 2,100 feet below the Pittsburgh Coal Bed; depth of well 1,947 feet. Jane Riddle farm, Mansfield, Allegheny County, Pennsylvania. (59533.)

(91) Very dark red, specific gravity 46½° Baumé. From the third sandstone of the Petroleum Measures; sand here 26 feet in thickness; oil in sand; depth of well 1,984 feet; drilled 1885; torpedoed; yielded 12 barrels of oil on first day of flow. Well No. 1, McCray farm, Ohio, Allegheny County, Pennsylvania. (59802.)

(92) Dark greenish red. From the Coal Measures sandstone. Old Brinker Well, Pleasant Valley, Westmoreland County, Pennsylvania. (59521.)

(93) Natural paraffin. From the Gordon sand of the Petroleum Measures. Gordon Well No. 1, Washington County, Pennsylvania. (59518.)

(94) Light greenish red, specific gravity 45° Baumé. From the Gordon sand of the Petroleum Measures. Shirl's Well No. 1, Washington County, Pennsylvania. (59524.)

(95) Light greenish red, specific gravity 44° Baumé. From the Gordon Sand, 2,098 feet below the Pittsburgh Coal Bed. Gantz Well, Washington, Washington County, Pennsylvania. (59525.)

(96) Light greenish red. From above the Gordon sand. Shirl's Well No. 2, Washington, Washington County, Pennsylvania. (59528.)

(97) Light greenish red, specific gravity 50° Baumé. From 1,855 feet below the Pittsburgh Coal Bed. Hess Well No. 2, Washington, Washington County, Pennsylvania. (59529.)

(98) Light red, specific gravity 51° Baumé. From the first sandstone of the Petroleum Measures (Venango), 1,813 feet below the Pittsburgh Coal Bed. Gordon Well, Washington, Washington County, Pennsylvania. (59530.)

(99) Greenish red. Montgomery Well, Washington, Washington County, Pennsylvania. (59531.)

(100) Greenish red. From 1,855 feet below the Pittsburgh Coal Bed. Smith Well, Washington, Washington County, Pennsylvania. (59532.)

(101) Light greenish red. From the Gordon sand. Miller Well No. 1, Gordon Pool, Washington County, Pennsylvania. (59590.)

(102) Light greenish red, specific gravity 45° Baumé. Gordon Well, Washington, Washington County, Pennsylvania. (59748.)

(103) Dark amber. Oil in sand, here 50 feet in thickness; depth of well 2,250 feet; drilled 1886; not torpedoed; yielded 350 barrels of oil on first day of flow. Well No. 1, Smith farm, Washington County, Pennsylvania. (59818.)

(104) Dark amber, specific gravity 46° Baumé. Oil in sand, here about 18 feet in thickness; depth of well 2,380 feet; drilled 1885; torpedoed; yielded 50 barrels of oil on first day of flow. Gordon Well, Gordon farm, Franklin, Washington County, Pennsylvania. (59794.)

(105) Greenish amber. Washington County, Pennsylvania. (59866.)

(106) Greenish amber. Washington County, Pennsylvania. (59867.)

(107) Light greenish red. From 180 feet below the Pittsburgh Coal Bed. Gilmore Well, Whitely Creek, Greene County, Pennsylvania. (59535.)

(108) Dark greenish red, specific gravity 44° Baumé. Lone Star Well. Greene County, Pennsylvania. (59738.)

(109) Dark greenish. Bradford County, Pennsylvania. (59868.)

(110) Dark greenish red, specific gravity 44° Baumé. Mount Nebo, Lancaster County, Pennsylvania. (59747.)

(111) Dark greenish. John Kennedy Well, Two Mile Run, Franklin County, Pennsylvania. (59503.)

(112) Dark greenish, specific gravity 44° Baumé. Phillip's Well, Pennsylvania. (59744.)

(113) Black. From the Carboniferous formation. Higgin's Well, Pleasants County, West Virginia. (59537.)

(114) Black, specific gravity 27.1° Baumé. From the Mill Stone grit (Carboniferous). Big Creek Well, near Volcano, Wood County, West Virginia. (59554.)

(115) Black, specific gravity 29° Baumé. From the Mill Stone grit (Carboniferous). Moore Well, near Volcano, Wood County, West Virginia. (59556.)

(116) Black, specific gravity 30.8° Baumé. From the Mill Stone grit (Carboniferous). Church Mill Well, near Volcano, Wood County, West Virginia. (59558.)

(117) Black, specific gravity 31.1° Baumé. From the Mill Stone grit (Carboniferous). A. Leasis Well, near Volcano, Wood County, West Virginia. (59559.)

(118) Dark greenish, specific gravity 32.7° Baumé. From the Mill Stone grit (Carboniferous). Whiskey Fork, near Volcano, Wood County, West Virginia. (59560.)

(119) Dark greenish, specific gravity 38.2° Baumé. From the Mill Stone Grit (Carboniferous). Lick Fork, near Volcano, Wood County, West Virginia. (59561.)

(120) Dark greenish, specific gravity 32° Baumé. From the first sandstone of the Great Conglomerate (Upper Carboniferous), and 980 feet below the Crinoidal Limestone; oil in sand; depth of well 420 feet. Volcanic Oil and Coal Company, White Oak district, Ritchie County, West Virginia. (59846.)

(121) Black, specific gravity 39° Baumé. From the first sandstone of the Great Conglomerate (Upper Carboniferous); oil in sand. Widow's Son Well, Volcanic Oil and Coal Company, White Oak district, Ritchie County, West Virginia. (59856.)

(122) Dark greenish, specific gravity 37° Baumé. From the first sandstone of the Great Conglomerate (Upper Carboniferous); oil in sand. West Virginia Oil and Oil Land Company, White Oak district, Ritchie County, West Virginia. (59859.)

(123) Dark greenish, specific gravity 34° Baumé. From the first sandstone of the Great Conglomerate (Upper Carboniferous); oil in sand. West Virginia Oil and Oil Land Company, White Oak district, Ritchie County, West Virginia. (59861.)

(124) Black. West Virginia. (59783.)

(125) Black. The first well in the United States that produced oil; drilled for salt in 1819. Beatty Well, Wayne County, Kentucky. (59833.)

(126) Dark greenish. From the first flowing well in the United States; drilled in 1829 for "brine." In 1860 it was drilled to the depth of 85 feet when it yielded 400 barrels of oil on the first day of flow. This sample is an original package as put up in 1856 and sold as a liniment or "Medicinal Oil." On the blank side was pasted a label with a cut of a brine well derrick. This picture is said to have suggested the idea of drilling a well for oil, and which was afterwards realized in Drake's Well that struck oil in August, 1859. American Well, Little Rennox Creek, near Burkesville, Kentucky. (59834.)

(127) Black. Boyd's Creek, near Glasgow, Barren County, Kentucky. (59830.)

(128) Dark greenish. Beaver Creek, near Glasgow, Barren County, Kentucky. (59831.)

(129) Amber, specific gravity 43° Baumé. From the Devonian formation, near Glasgow, Barren County, Kentucky. (59962.)

(130) Dark greenish. From the Upper Hudson formation. H. T. Motley farm, near Scottsville, Allen County, Kentucky. (59963.)

(131) Dark greenish, specific gravity 42° Baumé. Carroll Well No. 2, near Glasgow, Barren County, Kentucky. (59964.)

(132) Dark greenish, specific gravity 45.5° Baumé. Haven & Prase Well, near Glasgow, Barren County, Kentucky. (59965.)

(133) Dark greenish, specific gravity 35° Baumé. Adams Well, Boyd's Creek, Barren County, Kentucky. (59965.)

(134) Dark, specific gravity 41° Baumé. From the Lower Silurian formation. Jones Creek, Dickson County, Tennessee. (59573.)

(135) Black. Obtained by boring for sulphur on the Mississippi River, 100 miles north from New Orleans, Louisiana. (59549.)

(136) Black. Mecca, Trumbull County, Ohio. (59863.)

(137) Dark greenish, specific gravity 33° Baumé. From the Berea grit or fourth sandstone of the Petroleum Measures; drilled in 1886 as a test well. Cambridge, Guernsey County, Ohio. (59538.)

(138) Black. From the first sandstone of the Petroleum Measures (Mahoning). Geo. Rice Well, Macksburg, Washington County, Ohio. (59539.)

(139) Black. From the second sandstone of the Petroleum Measures (Mahoning). Geo. Rice Well, Macksburg, Washington County, Ohio. (59540.)

(140) Dark greenish. From the third sandstone of the Petroleum Measures (Mahoning). Geo. Rice Well, Macksburg, Washington County, Ohio. (59541.)

(141) Dark greenish. From the fourth sandstone of the Petroleum Measures. Macksburg, Washington County, Ohio. (59542.)

(142) Dark greenish, specific gravity 44° Baumé. From the first stray sand 650 feet below the Pittsburg coal bed. Longfellow & Stevens' Well, Macksburg, Washington County, Ohio. (59595.)

(143) Dark greenish. From the second stray sand, 775 feet below the Pittsburg coal bed. Longfellow & Stevens' Well, Macksburg, Washington County, Ohio. (59596.)

(144) Dark greenish, specific gravity on sample collected July, 1885, $39\frac{1}{2}^{\circ}$ Baumé. Oil in sand, here, 16 feet in thickness; depth of well 980 feet; drilled 1884; torpedoed; yielded 30 barrels of oil on first day of pumping. Washington County, Ohio. (59771.)

(145) Dark greenish. From the first sandstone of the Petroleum Measures (Mahoning); sand here 20 feet in thickness, and 100 feet below the Crinoidal limestone; oil in sand; depth of well 150 feet; drilled 1882; torpedoed; yielded 10 barrels of oil on first day of pumping. Farm of Frank Atkinson, Aurelius, Washington County, Ohio. (59854.)

(146) Black. Belden, Lorain County, Ohio. (59865.)

(147) Black, specific gravity 40° Baumé. From the Trenton limestone. Parker Well, Cygnet, Wood County, Ohio. (59764.)

(148) Black, specific gravity 32° Baumé. From the Trenton limestone. Mercer Well, near North Baltimore, Wood County, Ohio. (59565.)

(149) Black, specific gravity 37° Baumé. From the Trenton limestone. Bradshaw Well, near North Baltimore, Wood County, Ohio. (59567.)

(150) Black. From the Trenton limestone. Mathias Well, No. 1, Findlay, Hancock County, Ohio. (59545.)

(151) Dark greenish. From the Trenton limestone. P. P. Parker Well, near Findlay, Hancock County, Ohio. (59563.)

(152) Dark greenish. From the Trenton limestone. Findlay, Hancock County, Ohio. (59864.)

(153) Black. From the Trenton limestone. Reese Well, Lima, Allen County, Ohio. (59546.)

(154) Black. From the Trenton limestone. First Well, St. Mary's, Anglaize County, Ohio. (59547.)

(155) Black. Fauntanau, Ohio. (59721.)

(156) Black, specific gravity 34.5° Baumé. From the Trenton limestone. Winchester, Randolph County, Indiana. (59576.)

(157) Black. From the Hudson River group (Lower Silurian). Pioneer Well, Francisville, Pulaski County, Indiana. (59562.)

(158) Black. Test well drilled in 1887. Fort Scott, Bourbon County, Kansas. (59543.)

(159) Black, specific gravity 41° Baumé. California. (59742.)

THE TREATMENT OF PETROLEUM.

A very small amount of petroleum finds direct application in the preparation of special lubricators. Most petroleum is, however, subjected to distillation in order to obtain the various products in a state of purity suitable for particular uses.

Formerly it was the plan to subject the crude petroleum to plain distillation by heating it to certain regulated temperatures to separate the constituents volatile at these temperatures. By this operation only slight chemical changes took place during the operation, and there always remained a large amount of dark, heavy oil, having a strong odor, which found little or no application.

About 1865 the process of destructive distillation or "cracking" was introduced. This was so successful that it was rapidly adopted, and is now uniformly used in this country.

In this process the most volatile portions of the crude petroleum are first removed by plain distillation at about 100° C. The residue is then heated at once to a high temperature. By this operation the heavy oils are broken up "cracked" and a much larger yield of lighter oils suitable for illuminating purposes obtained; at the same time a considerable amount of gas is produced, which is utilized for heating purposes about the works. The residue remaining in the still constitutes only a small per cent. of the original crude petroleum, and is further treated.

The different distillates are subjected to a further treatment to prepare commercial products. Sometimes chemicals are used in this re-treatment. The final products are divided according to their specific gravity by the Baumé scale.

Professor Peckham gives the following tables* of the products from the process as ordinarily conducted. The first treatment at 100° C. gives off 12 to 15 per cent., which on retreatment yields:

	Per cent.
1. "Crude gasoline," to 80° , about	$\frac{1}{2}$
2. "C" naphtha, 80° to 68° , about	10
3. "B" naphtha, 68° to 64° , about	2 to $2\frac{1}{2}$
4. "A" naphtha, 64° to 60° , about	2 to $2\frac{1}{2}$

The residue subjected to cracking yields:

	Per cent.
1. Crude burning oil, from 58° to 40° , about	50
2. "B" oil, from 40° to 36° , about	20
3. From 36° downward, about	25
4. Cokings or residuum	3
5. Loss	2
	<hr/> 100

These products are treated in various ways to improve their quality, to separate the oils of different specific gravity, and to obtain the paraffin. The paraffin is separated by cooling the heavy oils containing it

* Tenth Census Report on Petroleum, vol. x, pp. 164 and 165.

to a very low temperature and subjecting it to pressure. The following table gives the final products:

	Per cent.
Gasoline	1.0 to 1.5
"C" naphtha.....	10.0
"B" naphtha.....	2.5
"A" naphtha.....	2.0 to 2.5
	16.5
Illuminating oil.....	50.0 to 54.0
Lubricating oil	17.5
Paraffin wax, 4½ pounds per barrel.....	2.0
Loss.....	10.0
	100.0

The treatment of petroleum is illustrated by a very large collection of 119 specimens, showing a great profusion of products, prepared by Mr. T. G. McMasters, Pittsburg, Pennsylvania.

The collection shows a series of the first distillates obtained, a very complete series of the commercial products obtained by refining these distillates, and some intermediate products.

The following twenty-seven specimens illustrate the first distillation:

- (1) Benzine, colorless; specific gravity 83° Baumé. (59602.)
- (2) Benzine, colorless; specific gravity 80° Baumé. (59603.)
- (3) Benzine, colorless; specific gravity 70° Baumé. (59604.)
- (4) Benzine, colorless; specific gravity 65° Baumé. (59605.)
- (5) Benzine, colorless; specific gravity 63° Baumé. (59606.)
- (6) Distillate, colorless; specific gravity 60° Baumé. (59607.)
- (7) Distillate, colorless; specific gravity 55° Baumé. (59608.)
- (8) Distillate, colorless; specific gravity 50° Baumé. (59609.)
- (9) Distillate, colorless; specific gravity 48° Baumé. (59610.)
- (10) Distillate, nearly colorless; specific gravity 46° Baumé. (59611.)
- (11) Distillate, nearly colorless; specific gravity 45° Baumé. (59612.)
- (12) Distillate, nearly colorless; specific gravity 43° Baumé. (59613.)
- (13) Distillate, light straw color; specific gravity 40° Baumé. (59514.)
- (14) Distillate, dark greenish red; specific gravity 38° Baumé. (59615.)
- (15) Paraffin distillate, light brown; specific gravity 42° Baumé. (59623.)
- (16) Paraffin distillate, dark red; specific gravity 38° Baumé. (59624.)
- (17) Paraffin distillate, dark greenish red; specific gravity 35° Baumé. (59625.)
- (18) Paraffin distillate, dark greenish red; specific gravity 30° Baumé. (59626.)
- (19) Paraffin distillate, dark greenish; specific gravity 29° Baumé. (59627.)
- (20) Paraffin distillate, dark greenish; specific gravity 27° Baumé. (59628.)
- (21) Paraffin distillate, dark greenish; specific gravity 25° Baumé. (59629.)
- (22) Paraffin distillate, dark greenish; specific gravity 24 Baumé. (59630.)
- (23) Paraffin distillate, dark greenish; specific gravity 22° Baumé. (59631.)
- (24) Paraffin distillate, greenish brown; specific gravity 16° Baumé. (59632.)
- (25) Tailings, light brown. (59633.)
- (26) Residuum, still residue, black; specific gravity 18° Baumé. (59641.)
- (27) Residuum, still residue, black; specific gravity 20° Baumé. (59642.)

The following specimens illustrate various grades of commercial oils:

- (1) Gasoline, colorless; specific gravity 103° Baumé. (59616.)
- (2) Gasoline, colorless; specific gravity 95° Baumé. (59617.)
- (3) Gasoline, colorless; specific gravity 88° Baumé. (59618.)

- (4) Gasoline, colorless; specific gravity 80° Baumé. (59619.)
- (5) Gasoline, colorless; specific gravity 74° Baumé. (59620.)
- (6) Naphtha, colorless; specific gravity 70° Baumé. (59621.)
- (7) Sweet naphtha, colorless; specific gravity 63° Baumé. (59622.)
- (8) Illuminating oil, standard white; specific gravity 45° Baumé; fire test 110° F. (59645.)
- (9) Illuminating oil, standard white; specific gravity 46° Baumé; fire test 115° F.; flash test (Abel) 70° F. (59646.)
- (10) Illuminating oil, standard white; specific gravity 46° Baumé; fire test 120° F.; flash test (Abel) 73° F. (59647.)
- (11) Illuminating oil, standard white; specific gravity 49.5° Baumé; fire test 120° F. (59648.)
- (12) Illuminating oil, standard white; specific gravity 46° Baumé; fire test 130° F.; flash test 100° F. (59649.)
- (13) Illuminating oil, prime white; specific gravity 46.5° Baumé; fire test 130° F. (59650.)
- (14) Illuminating oil, water white; specific gravity 49.5° Baumé; fire test 130° F. (59651.)
- (15) Illuminating oil, standard white; specific gravity 46° Baumé; fire test 140° F. (59652.)
- (16) Illuminating oil, prime white; specific gravity 47.5° Baumé; fire test 140° F. (59653.)
- (17) Illuminating oil, prime white; specific gravity 48° Baumé; fire test 150° F. (59655.)
- (18) Illuminating oil, water white; specific gravity 49° Baumé; fire test 140° F. (59654.)
- (19) Illuminating oil, water white; fire test 150° F. (59656.)
- (20) Illuminating oil, standard white; specific gravity 46.5 Baumé; fire test 155° F.; flash test 120° F. (59657.)
- (21) Illuminating oil, prime white; specific gravity 47.5° Baumé; fire test 160° F.; flash test 125° F. (59658.)
- (22) Illuminating oil, water white; specific gravity 49° Baumé; fire test 160° F. (59659.)
- (23) Illuminating oil, prime white; specific gravity 47.5° Baumé; fire test 175° F. (59660.)
- (24) Illuminating oil, water white; specific gravity 48° Baumé; fire test 175° F. (59661.)
- (25) Illuminating oil, water white; specific gravity 47.5° Baumé; fire test 200 F. (59662.)
- (26) Illuminating oil, colorless; specific gravity 40° Baumé; fire test 250° F. (59663.)
- (27) Illuminating oil, refined, colorless; specific gravity 41° Baumé; fire test 300° F. (59664.)
- (28) Illuminating oil, refined, colorless; specific gravity 38.5° Baumé; fire test 300° F. (59665.)
- (29) Illuminating oil, amber burning; specific gravity 43° Baumé; fire test 150° F. (59666.)
- (30) Illuminating oil, refined amber burning; specific gravity 42° Baumé; fire test 200° F. (59667.)
- (31) Illuminating oil, red oil; specific gravity 48° Baumé; fire test 150° F. (59668.)
- (32) Dark signal oil, light straw color; specific gravity 36° Baumé; fire test 300° F. (59669.)
- (33) Light signal oil, straw color; specific gravity 38° Baumé; fire test 300° F. (59670.)
- (34) Unbleached neutral oil, straw color; specific gravity 36° Baumé. (59671.)

(35) White neutral oil, specific gravity 36° Baumé; fire test 360° F. (59672.)

(36) White neutral oil, specific gravity 38° Baumé. (59673.)

(37) Yellow neutral oil, specific gravity 33° Baumé. (59674.)

Ten grades of paraffin oil are shown, as follows:

(1) Light amber, specific gravity 30° Baumé; fire test 275° F. (59675.)

(2) Dark amber, specific gravity 29° Baumé; fire test 275° F.; cold test 30° F. (59676.)

(3) Dark amber, specific gravity 28° Baumé; fire test 300° F.; cold test 35° F. (59677.)

(4) Dark amber, specific gravity 27° Baumé; fire test 300° F.; cold test 40° F. (59678.)

(5) Light amber, specific gravity 26° Baumé; fire test 300° F.; cold test 25° F. (59679.)

(6) Light amber, specific gravity 25° Baumé; fire test 300° F.; cold test 20° F. (59680.)

(7) Dark amber, specific gravity 24° Baumé; fire test 350° F.; cold test 25° F. (59681.)

(8) Dark amber, specific gravity 23.5° Baumé; fire test 350° F.; cold test 45° F. (59683.)

(9) Dark amber, specific gravity 23° Baumé; fire test 375° F.; cold test 35° F. (59682.)

(10) Light greenish brown, specific gravity 22° Baumé; fire test 400° F.; cold test 25° F. (59684.)

Oils suitable for lubricating purposes are illustrated by twenty-one specimens:

(1) Engine oil, dark greenish red; specific gravity 25° Baumé; fire test 350° F. (59686.)

(2) Cylinder oil, dark greenish red; specific gravity 29° Baumé; fire test 400° F. (59691.)

(3) Cylinder oil, dark greenish; specific gravity 28° Baumé; fire test 500° F. (59692.)

(4) Cylinder oil, dark greenish red; specific gravity 28° Baumé; fire test 450° F. (59693.)

(5) Cylinder oil, filtered; dark greenish red; specific gravity 28° Baumé; fire test 400° F. (59694.)

(6) Cylinder oil, dark greenish; specific gravity 28° Baumé; fire test 600°; cold test 25° F. (59695.)

(7) Cylinder oil, dark greenish; specific gravity 27° Baumé; fire test 400° F. (59696.)

(8) Cylinder oil, dark greenish; specific gravity 26.5° Baumé; fire test 600° F.; cold test 20° F. (59697.)

(9) Cylinder oil, dark greenish; specific gravity 25° Baumé; fire test 500° F. (59698.)

(10) Cylinder oil, black; specific gravity 25° Baumé; fire test 600° F. (59699.)

(11) Cylinder oil, dark greenish; specific gravity 28° Baumé; fire test 550° F.; cold test 25° F. (59700.)

(12) Lubricating oil, dark greenish brown; specific gravity 29° Baumé; fire test 300° F. (59701.)

(13) Lubricating oil, dark greenish brown; specific gravity 28° Baumé; fire test 350° F. (59702.)

(14) Lubricating oil, dark brown; specific gravity 37° Baumé; fire test 400° F. (59703.)

(15) Lubricating oil, dark brown; specific gravity 26° Baumé; fire test 400° F. (59704.)

(16) Lubricating oil, specific gravity 25° Baumé; fire test 500° F. (59705.)

- (17) Lubricating oil, specific gravity 15° below zero 29° Baumé; fire test 250° F. (59706.)
- (18) Lubricating oil, specific gravity 27° Baumé. (59707.)
- (19) Lubricating oil, specific gravity 29° Baumé; fire test 275° F.; cold test zero. (59708.)
- (20) Lubricating oil, specific gravity 29° Baumé; cold test 25° F. (59709.)
- (21) Lubricating oil, specific gravity 28° Baumé; fire test 325° F.; cold test 30° F. (59710.)

The separation and preparation of paraffin is illustrated by:

- (1) Gum wax, light brown. (59634.)
- (2) Pressed oil, dark greenish; specific gravity 25° Baumé. (59635.)
- (3) Paraffin oil, treated amber; specific gravity 25° Baumé. (59636.)
- (4) Crude wax, black, slack pressed; chill test 102° F. (59637.)
- (5) Crude wax, treated amber; chill test 108° F. (59638.)
- (6) Treated wax, hydraulic pressed; chill test 129° F. (59639.)
- (7) Refined wax, white; chill test 145° F. (59640.)

The following specimens represent various solids obtained:

- (1) Petroleum pitch, black; melting point 115° F. (59712.)
- (2) Vaseline or petroleum salve. (59713.)
- (3) Petroleum jelly. (59714.)
- (4) Carboline or hair-oil. (59715.)
- (5) Journal grease, black; melting point 80° F. (59716.)
- (6) Wagon grease, melting point 120° F. (59717.)
- (7) Hot neck mill grease, melting point 140° F. (59718.)
- (8) Cold neck mill grease, melting point 110° F. (59719.)
- (9) Tar coke, carbon. (59643.)
- (10) Electric light carbon points, made from tar coke. (59644.)

In this connection three specimens are shown to illustrate reduced oils, which are lubricating oils prepared by the slow evaporation at comparatively low temperatures of the volatile constituents of special crude petroleum:

- (1) Reduced oil, for lubricating purposes, dark greenish red; specific gravity 38° Baumé. (59687.)
- (2) Reduced oil, for lubricating purposes, dark greenish red; specific gravity 36° Baumé. (59688.)
- (3) Reduced oil, dark greenish red; specific gravity 34° Baumé. (59689.)

GASEOUS BITUMEN.

NATURAL GAS.

Composition: Very variable. The following six analyses of samples taken from the same well show wide variation:

	(a)	(b)	(c)	(d)	(e)	(f)
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Marsh gas.....	57.85	75.16	72.18	65.25	60.70	49.58
Hydrogen.....	9.64	14.45	22.02	26.16	29.03	35.92
Ethyllic hydride.....	5.20	4.80	3.60	5.50	7.92	12.50
Olefiant gas.....	0.80	0.60	0.70	0.80	0.98	0.60
Oxygen.....	2.10	1.20	1.10	0.80	0.78	0.80
Carbonic oxide.....	1.00	0.30	1.00	0.80	0.58	0.40
Carbonic acid.....	0.00	0.30	0.80	0.60	0.00	3.40
Nitrogen.....	23.41	2.89	0.00	0.00	0.00	0.00

Wherever organic material is exposed to decomposing influences gas is very sure to be given off, but it is only when this decomposition occurs under conditions suitable for storing and saving the gas that it becomes of practical value.

Natural gas has been used in small quantities for heating and lighting for many years, but recently the discovery of abundant supplies of gas in New York, Pennsylvania, Ohio, and Indiana has led to its extensive employment for heating and lighting upon a large scale. It is illustrated by a single specimen only as there is so little difference apparent between different samples. (59989.)

11-24 C H

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